PB-242 526

ASSESSMENT OF DOMESTIC AUTOMOTIVE INDUSTRY PRODUCTION LEAD TIME OF 1975/76 MODEL YEAR

VOLUME II - TECHNICAL DISCUSSION

Aerospace Corporation

PREPARED FOR
Environmental Protection Agency

December 1972

DISTRIBUTED BY:
NTIS
National Technical Information Service
U. S. DEPARTMENT OF COMMERCE

EPA-460/3-74-026-b

DECEMBER 1972

141111

PB242526

ASSESSMENT OF DOMESTIC AUTOMOTIVE INDUSTRY PRODUCTION LEAD TIME OF 1975/76 MODEL YEAR: VOLUME II - TECHNICAL DISCUSSION

FINAL REPORT

Reproduced by
NATIONAL TECHNICAL
INFORMATION SERVICE
US Department of Commerce
Springfield, VA. 22151

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Air and Waste Management
Office of Mobile Source Air Pollution Control
Emission Control Technology Division
Ann Arbor, Michigan 48105

TECHNICAL REPORT DATA

(Please read Instructions on the reverse before completing)

1. REPORT NO EPA-460/3-74-026-b	2.	3 PB 242 526
4. TITLE AND SUBTITLE Assessment of Domestic Automotive Industry Production Lead Time for 1975/76 Model year Volume II - Technical Discussion		5. REPORT DATE Dec. 1972
		6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) D.E. Lapedes, M.G. Hinton, T. Iura, and J. Meltzer		8. PERFORMING ORGANIZATION REPORT NO. ATR-73(7321)-1
9. PERFORMING ORGANIZATION NAME AND ADDRESS Aerospace Corp. El Segundo, Calif		10. PROGRAM ELEMENT NO.
		11. CONTRACT/GRANT NO. 68-01-0417
12. SPONSORING AGENCY NAME AND ADDRESS Environmental Protection Agency Emission Control Technology Division Ann Arbor, Michigan 48105		13. TYPE OF REPORT AND PERIOD COVERED Final
		14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

16. ABSTRACT

A survey and analysis of the factors involved in bringing automobiles into the market place with emphasis on production engineering, prototype testing and tooling for production of the automobile and the oxidizing catalyst.

7. KEY WORDS AND DOCUMENT ANALYSIS

DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Automobile Manufacturing Lead-Time Catalysts Production tools		

PRICES SUBJECT TO CHANGE

8. DISTRIBUTION STATEMENT Release Unlimited	19. SECURITY CLASS *(This Report)* Unclassified	21. NO. OF PAGES 375
	20. SECURITY CLASS *(This page)* Unclassified	22. PRICE 10.00/2.25

i.

EPA-460/3-74-026-b

ASSESSMENT OF DOMESTIC AUTOMOTIVE INDUSTRY PRODUCTION LEAD TIME OF 1975/76 MODEL YEAR:
VOLUME II - TECHNICAL DISCUSSION
FINAL REPORT

Prepared by
D.E. Lapedes, M.G. Hinton, Toru Iura, and Joseph Meltzer
Aerospace Corp.
El Segundo, California

Contract No. 68-01-0417

EPA Project Officer: F. Peter Hutchins

Prepared for
U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Air and Waste Management
Office of Mobile Source Air Pollution Control
Emission Control Technology Division
Ann Arbor, Michigan 48105

December 1972

This report is issued by the Environmental Protection Agency to report technical data of interest to a limited number of readers. Copies are available free of charge to Federal employees, current contractors and grantees, and nonprofit organizations - as supplies permit - from the Air Pollution Technical Information Center, Environmental Protection Agency, Research Triangle Park, North Carolina 27711; or, for a fee, from the National Technical Information Service, 5285 Port Royal Road, Springfield, Virginia 22161.

This report was furnished to the Environmental Protection Agency by Aerospace Corp., El Segundo, California, in fulfillment of Contract No. 68-01-0417. The contents of this report are reproduced herein as received from Aerospace Corp. The opinions, findings, and conclusions expressed are those of the author and not necessarily those of the Environmental Protection Agency. Mention of company or product names is not to be considered as an endorsement by the Environmental Protection Agency.

Publication No. EPA-460/3-74-026-b

FOREWORD

This report, prepared by The Aerospace Corporation for the Environmental Protection Agency, Division of Emission Control Technology, presents an assessment of available information pertaining to the production lead time requirements of the automotive industry for 1975/76 model year automobiles.

The status of the production lead time reported herein is that existing at the time of data acquisition visits made to selected firms in the period August 1, 1972 through October 5, 1972. The results of this study are presented in two volumes. Volume 1, the Executive Summary, presents a brief, concise review of important findings and conclusions in the Highlights and Executive Summary sections. Volume 2, the Technical Discussion, provides a comprehensive discussion of each study topic and is of interest primarily to the technical specialist. In Volume 2 a brief discussion of basic automotive product development phases is given in Section 2. A summary of emission control systems currently proposed by domestic automobile manufacturers for model years 1975/76 is presented in Section 3. The assessment of the industry's production lead time requirements, with particular emphasis on the impact of critical emission control system components and subsystems, is discussed in Section 4. Specific lead time schedules obtained from automobile manufacturers, catalyst and substrate manufacturers, automobile component manufacturers, and production equipment manufacturers are given in Sections 5 through 8. Similar lead time schedules for nonautomotive industry manufacturers and for a government automotive procurement agency are presented in Sections 9 and 10, respectively. Section 11 contains a discussion of platinum-group metal production and usage. Finally, Appendix A, Section 12, contains a listing of the companies visited in the data acquisition activity.

ACKNOWLEDGMENT

Appreciation is acknowledged for the guidance and continued assistance provided by Mr. F. P. Hutchins of the Environmental Protection Agency, Division of Emission Control Technology, who served as EPA Project Officer for this study.

The following technical personnel of The Aerospace Corporation made valuable contributions to the assessment performed under this contract.

L. Forrest
O. Hamberg
R. B. Laube
W. U. Roessler
W. M. Smalley
K. B. Swan

D E Lapedes

D. E. Lapedes, Manager
Production Lead Time Study

Approved by:

Merrill G Hinton

Merrill G. Hinton, Director
Office of Mobile Source Pollution

Toru Iura, Assistant Group Director
Environmental Programs
Group Directorate

Meltzer

Joseph Meltzer, Group Director
Environmental Programs
Group Directorate

HIGHLIGHTS

A summarization and assessment were made of available information pertaining to the production lead time[1] requirements of the domestic automotive industry for 1975/76 model year automobiles. Assessment of the status of the industry as of the time of data acquisition visits and technical discussions (August 1 to October 5, 1972) resulted in the following findings.

1. General Motors, Ford, Chrysler, and American Motors are currently proceeding on 1975 model year production schedules which call for the start of full mass production at the normal new model production start date of August 1974.

2. All domestic automobile manufacturers have basically similar 1975 production schedules which are consistent with the historically established guideline for management approval of the new model car development program at approximately 28 months prior to mass production initiation.

3. These 1975 production schedules include provisions for the incorporation of an emission control system consisting of an oxidation catalytic converter, exhaust gas recirculation, air injection, improved carburetion and ignition, and devices or techniques to promote fast warmup of the induction system and catalytic converter.

4. The catalytic converter is identified by all automobile manufacturers as the most critical production lead time item in their schedule. It is schedule-controlling because of the lead time required by suppliers to develop facilities for mass producing both substrates and finished catalysts (approximately 2 years).

5. The lack of satisfactory test results from prototype automobile test programs is having a major impact upon the decisions of automobile manufacturers pertaining to final catalyst commitments. To date, no domestic manufacturer has successfully completed mileage accumulation tests to 50,000 miles, although some prototypes have come close to meeting the emission standards at extended mileage. The automobile manufacturers have, therefore, placed orders for long lead time

---

[1] Production lead time is herein defined as that time period allocated or required for the refinement of mass manufacturing techniques, construction of manufacturing facilities, and the procurement and installation of equipment.

equipment and tooling based on their best judgment as to what will constitute a final design. Some companies still have to choose between pellet and monolith substrates and between promoted base metal and platinum-group metal catalysts. Many final commitments to substrate and catalyst manufacturers are being delayed as long as possible in order to have more data available before making such high risk decisions.

6. Partial and staged financial commitments to catalyst and substrate manufacturers have been made by the various automobile manufacturers in order to enable the catalyst manufacturers to initiate preliminary facility design and site selection activities. However, final commitments to the catalyst suppliers are required before facility construction will be initiated.

7. Available estimates of capital cost requirements per individual supplier are in the range of $4 to $5 million for substrate production facilities, and $4 to $15 million for catalyst production facilities with capacities ranging between 3 and 10 million units per year. At these cost levels, the substrate and catalyst manufacturers will not commit venture capital without a firm production contract or other form of guarantee. It is this fact which presently most strongly impacts the projected catalyst lead time schedules, since the required production facility construction will not commence until such agreements are successfully concluded.

8. Current production lead time schedules of contending substrate and catalyst manufacturers require production order commitments, or other forms of venture capital guarantees, from the automobile manufacturers by November to December 1972 in order to ensure quantity production of oxidation catalysts in time for 1975 model year vehicles. In every case, the critical, or pacing, item in the overall catalyst production lead time schedule is the time required by the vendor for the design of the production facilities, site selection, and construction of the facility or plant.

9. The status of contractual agreements between the automobile manufacturers and the catalyst manufacturers is one of uncertainty and change because serious negotiations were apparently under way during the period of investigation (August to October 1972). Most commitments to date have been of a preliminary nature and only cover funding for preliminary engineering design of production facilities and site selection. These initial commitments have enabled the automobile companies to defer their final commitments until the November to December 1972 time period. Of the known agreements, the Ford/Englehard agreement is the most extensive, with Ford commitments rising to about $10 million in March 1973 (when product-design-oriented equipment and facilities are to be purchased) and to $14 million by April 1974.

10. Substrate manufacturers state, in general, that no appreciable lead time compression can be made at the present level of schedule definition. In the finished catalyst area, there is some hope of minor schedule compressions (from 0 to 3 months for monoliths; 3 to 6 months for pellet catalysts). Estimates of cost penalties for such schedule compressions range from negligible to 10 percent product cost increases for overtime pay and increased capital costs.

11. Mass production of oxidation catalysts of the automotive type has never been accomplished by any company; however, the catalyst firms believe that related production and quality control techniques (in the chemical and petrochemical industries) provide a firm basis for assurance that their proposed production lead time schedules can be met. The automobile companies, however, have expressed some reservations about the capability of the catalyst manufacturers to mass produce the catalysts in the volume necessary while maintaining quality control.

12. If substrate, finished catalyst, and converter canister elements used in certification test vehicles are not made with production equipment (e.g., if batch processing rather than continuous processing, soft tooling, etc., are used), it may raise an issue as to whether or not the catalytic converter tested was the same "in all material respects" as production units. Items of concern in this regard include catalyst loading, uniformity of loading, substrate physical properties, and canister dimensional, physical, and weldment characteristics.

13. The production lead time requirements of conventional automobile component suppliers (body stampings, frames, transmissions, carburetors, exhaust systems, wheels, brake parts, etc.) appear to be adequately met by currently projected automobile manufacturer design release and/or vendor commitment dates. The key schedule dates for such component suppliers are those for the delivery of production samples to the automobile manufacturer for certification test vehicles and for car pilot line production.

14. Conventional production equipment items (automatic transfer lines, cold stamping presses, resistance welders, etc.) can be procured as required within the lead time remaining for 1975 model year automobiles. Electron beam welders, required for edge-welding of the General Motors pelletized catalytic converter canister, are being manufactured by Hamilton Standard on a schedule consistent with the 1975 production requirements of General Motors.

15. The current production capacity of platinum-group metals in the world is not sufficient to satisfy projected requirements of the automotive industry in the United States in the post-1975 time period. However, the demand can be met by the opening of new mines in South Africa. In order to ensure adequate platinum-group metal availability in the 1975 to 1980 time period, final contract agreements between the automobile manufacturers and the South African platinum-group metal mining firms must be signed in the near future.

16. The platinum-group metal supply-demand balance is determined by the platinum-group metal loading requirement, the number of catalysts required for the various vehicle classes, the catalyst replacement interval, the mining industry capacity, and the degree of platinum-group metal recovery from spent catalysts. A thorough study of these parameters is urgently needed in order to provide all the data required for a complete and meaningful assessment of the platinum-group metal availability and demand issues.

17. The automotive industry's stainless steel requirements for the 1975 model year (for exhaust systems, catalytic converter canisters, thermal reactor liners, etc.) have not been fully quantified as to type and amount. Raw material availability is not a problem, but material processing capacity may be a problem unless the additional equipment required is ordered in a timely manner.

18. The 50,000-mile durability certification test requires approximately 5 to 6 months to complete. In order to provide for the contingency of durability test vehicle failure, the first durability test should start no later than September 1973 if two full durability test periods are desired (based on an August 1974 vehicle production start date).

19. Emission control systems currently under consideration for use in 1976 model year vehicles incorporate all components of the 1975 system plus a reduction (NO_x) catalyst(s), more sophisticated air injection systems, and further modifications to carburetion, ignition, and exhaust gas recirculation systems. Production lead time schedules for the 1976 model year have not yet been disclosed by the automobile manufacturers due to the uncertainty attending critical lead time elements of the 1975 model year production schedules and the lack of satisfactory development of reduction catalysts for control of oxides of nitrogen.

20. The full-size thermal reactor is not considered a viable option or alternative to the catalytic converter for 1975 model year vehicles, as the thermal reactor is not fully developed and the automobile companies have not ordered the long lead time production equipment required for its manufacture. Ford states that the time is now past the critical point for ordering such foundry equipment for 1975 model year production. The foundry industry (exclusive of automobile company foundries) indicates that if additional foundry capacity on its part would be required, it would take 36 months to bring it to full production status.

21. Less effective partial thermal reactors, smaller in volume and less complex than full-size reactors, are currently programmed for use in 1975 emission control systems. These could be used without catalytic converters but the resulting emission reduction capability is at present not well defined and could vary among the different automobile manufacturers, according to individual design details.

Some statements made herein may make it appear that the 1975 model year automobile production schedules have changed with time since they were originally presented at the EPA Suspension Request Hearings in April 1972. However, the overall lead time schedules have remained relatively constant during the intervening period. Adherence to these schedules has been accomplished by making (a) timely design decisions as required, (b) minor compressions in supplier lead time schedules, and (c) partial or staged commitments in critical long lead time areas.

The risk to the automobile firms in following the original lead time schedules has been increasing with time. This is due to the fact that decisions in accordance with schedule milestones have had to be made with incomplete data regarding the adequacy of proposed emission control systems. Therefore, it would appear that the current production lead time schedules will permit 1975 model year production to begin in August 1974, unless the automobile manufacturers judge that the systems under development are so unsatisfactory that further commitments will not be made on the dates required.

CONTENTS

VOLUME II

FOREWORD iii

ACKNOWLEDGEMENT v

HIGHLIGHTS vii

1. INTRODUCTION 1-1

2. AUTOMOTIVE PRODUCT DEVELOPMENT PHASES 2-1
   - 2.1 Introduction 2-1
   - 2.2 Fundamental Definitions 2-1
   - 2.3 Product Development Cycle Overview 2-2
   - 2.4 Product Development Phases 2-3

3. PROPOSED 1975/76 MODEL YEAR AUTOMOBILE EMISSION CONTROL SYSTEMS 3-1
   - 3.1 Introduction 3-1
   - 3.2 Projected 1975/76 Emission Control Systems 3-1

4. ASSESSMENT OF AUTOMOBILE MANUFACTURERS' PRODUCTION LEAD TIME 4-1
   - 4.1 Introductory Remarks 4-1
   - 4.2 Historical Review 4-2
   - 4.3 Influence of Emission Control System 4-5
   - 4.4 Influence of Prototype Test Program 4-10
   - 4.5 Effect of Certification Test Program 4-12
   - 4.6 Degree of Industry Schedule Consistency 4-12
   - 4.7 Potential for Industry Schedule Compression 4-14
   - 4.8 Industry Capacity to Meet High Production Volume 4-16
   - 4.9 Technological Implications of Alternative Plans . . . 4-25
   - 4.10 Prognosis for 1975/76 Lead Time Requirements . . . 4-27

CONTENTS (Continued)

VOLUME II

5. LEAD TIME SCHEDULES FOR AUTOMOBILE MANUFACTURERS 5-1
   - 5.1 General Motors 5-2
   - 5.2 Ford Motor Company 5-27
   - 5.3 Chrysler Corporation 5-50
   - 5.4 American Motors Corporation 5-69
6. LEAD TIME SCHEDULES FOR CATALYST AND SUBSTRATE MANUFACTURERS 6-1
   - 6.1 Summary Discussion 6-1
   - 6.2 American Lava Corporation 6-19
   - 6.3 Corning Glass Works 6-30
   - 6.4 Engelhard Minerals and Chemicals Corporation . . . 6-41
   - 6.5 W. R. Grace and Company 6-48
   - 6.6 Gulf Oil Company 6-56
   - 6.7 Kaiser Aluminum and Chemical Corporation 6-60
   - 6.8 Matthey Bishop, Inc. 6-66
   - 6.9 Monsanto Company 6-78
   - 6.10 Oxy-Catalyst, Inc. 6-89
   - 6.11 Reynolds Metals Company 6-99
   - 6.12 Universal Oil Products Company 6-105
7. LEAD TIME SCHEDULES FOR AUTOMOBILE COMPONENT MANUFACTURERS 7-1
   - 7.1 Lead Time Schedules for Body Stampings 7-3
   - 7.2 Lead Time Schedules for Frames 7-8
   - 7.3 Lead Time Schedules for Transmissions 7-11
   - 7.4 Lead Time Schedules for Carburetors 7-14
   - 7.5 Lead Time Schedule for Exhaust Systems 7-18
   - 7.6 Lead Time Schedules for Wheels and Brake Parts 7-18

CONTENTS (Continued)

VOLUME II

7.7 Lead Time for Other Components 7-22

8. LEAD TIME SCHEDULES FOR PRODUCTION EQUIPMENT MANUFACTURERS 8-1

8.1 Lead Time Schedules for Automatic Transfer Lines 8-1

8.2 Lead Time Schedules for Cold Stamping Presses 8-6

8.3 Lead Time Schedules for Welders 8-13

9. LEAD TIME SCHEDULES FOR NONAUTOMOTIVE INDUSTRY MANUFACTURERS 9-1

9.1 Introduction 9-1

9.2 The Westinghouse Corporation - Columbus, Ohio 9-1

9.3 The General Electric Company - Louisville, Kentucky 9-6

9.4 The Outboard Marine Corporation - Milwaukee, Wisconsin 9-9

9.5 Automotive Versus Nonautomotive Lead Time Comparison 9-12

10. LEAD TIME SCHEDULES FOR A GOVERNMENT AUTOMOTIVE PROCUREMENT AGENCY 10-1

10.1 Normal Production Schedules for Government Vehicles 10-1

10.2 Major Impact Factors for Government Vehicles 10-6

11. PROJECTED WORLD PRODUCTION AND USAGE OF NOBLE METALS 11-1

11.1 Introduction 11-1

11.2 World Production of Noble Metals 11-1

11.3 Usage of Noble Metals 11-11

11.4 Noble Metal Supply-Demand Considerations 11-16

11.5 Conclusions 11-22

CONTENTS (Continued

VOLUME II

APPENDICES

A. Companies Visited A-1
B. Bibliography B-1

FIGURES

VOLUME II

2-1 Automotive Product Development Phases 2-4

3-1 Chrysler A-335 Special Emission Car (System Features) 3-5

3-2 Ford 1975 "Kitchen Sink" Emission Control System 3-7

3-3 General Motors Projected 1975 Under-Floor Emission Control System 3-9

3-4 General Motors Triple-Mode Emission Control System (T-MECS) – Catalytic Converter (Startup Oxidizing Mode) 3-10

4-1 Lead Time Trends 4-4

4-2 Overall Production Lead Time Schedules 4-13

5-1 General Motors Master Timing Schedule for 1975 Emission Components 5-3

5-2 General Motors Production Equipment Development Schedule for 1975 Model Year Under-Floor Oxidizing Catalytic Converter (Compressed Schedule) 5-6

5-3 General Motors Production Equipment Development Schedule for Manifold-Mounted Oxidizing Catalytic Converter (Compressed Schedule) 5-7

5-4 General Motors New Carburetor Lead Time 5-8

5-5 General Motors Composite Times to Secure Equipment (Under-Floor Catalytic Converter) 5-11

5-6 General Motors Process Development and Manufacturing Time Table for Under-Floor Oxidizing Catalytic Converter ("Normal" Schedule) 5-16

5-7 General Motors Apache Two-Barrel Throttle Body Integrated Lead Time 5-25

5-8 Ford Overall Schedule: 1975 Vehicle and Emission Engine Program 5-28

5-9 Ford 1975 Car Line Program 5-35

5-10 Ford 1975 Model Federal Emission Program and Passenger Car Timing Plan 5-37

FIGURES (Continued)

VOLUME II

5-11 Engine/Emission Hardware Testing and Scheduling 5-42
5-12 Vendor Timing Requirements 5-46
5-13 Ford Catalytic Converter Program Timing 5-47
5-14 Chrysler Overall Schedule for the 1975 Emission Control System 5-52
5-15 Chrysler 1975 Production Development Schedule for Major Frame and Body Components 5-56
5-16 Chrysler 1975 Production Development Schedule for Electronic Spark Advance plus Electronic EGR Control 5-58
5-17 Chrysler 1975 Production Development Schedule for Catalytic Converter System 5-59
5-18 Chrysler 1975 Production Development Schedule for Carburetors 5-62
5-19 Chrysler 1973 Production Development Schedule for Major "B" Body Sheet Metal 5-64
5-20 American Motors 1975 Emission Control Program Timing Study 5-70
5-21 American Motors 1975 Catalytic Converter and Associated Body Changes Time Study 5-74
5-22 American Motors Summary Network of Product Creation 5-78
6-1 Monolithic Catalytic Converters, Typical Flow of Responsibilities (Examples Only) 6-2
6-2 Pelletized Catalytic Converters, Typical Flow of Responsibilities (Examples Only) 6-3
6-3 Production Lead Time Schedule for Catalyst Manufacturers 6-8
6-4 Production Lead Time Schedule for Substrate Manufacturers 6-9
6-5 American Lava Stacked and Rolled Corrugated Structures 6-20

FIGURES (Continued)

VOLUME II

6-6 American Lava Corrugated Structure Types 6-21

6-7 American Lava Initially Projected Schedule for Manufacturing Scale-Up 6-24

6-8 American Lava Revised Production Lead Time Schedule (Chattanooga Facilities) 6-26

6-9 Corning Substrate Geometries 6-32

6-10 Corning Production Lead Time Schedule 6-35

6-11 Engelhard Production Lead Time Schedule, Plant No. 1 6-43

6-12 Engelhard Production Lead Time Schedule, Plant No. 2 6-44

6-13 Kaiser Production Lead Time Schedule 6-62

6-14 Matthey Bishop Production Lead Time Schedule 6-70

6-15 Monsanto Functional Step Chart--Automotive Exhaust Catalyst Project 6-81

6-16 Monsanto Production Lead Time Schedule (ECA Oxidation Catalyst Plant) 6-82

6-17 Oxy-Catalyst Production Lead Time Schedule (Pellet or Monolithic Catalysts) 6-92

6-18 Oxy-Catalyst/Contractor/Supplier Relationships; Oxidation Catalyst Plant 6-96

6-19 UOP Production Lead Time Schedule 6-108

7-1 Automobile Component Manufacturers' Overall Production Lead Time 7-2

7-2 Extended Roof Panel for the Ford Econoline Van 7-4

7-3 Body Stamping Lead Time 7-6

7-4 Frame Lead Time 7-9

7-5 Transmission Lead Time 7-12

7-6 Carburetor Lead Time 7-16

7-7 Exhaust System Lead Time 7-19

FIGURES (Continued)

VOLUME II

7-8 Wheels and Brake Parts Lead Time 7-20
7-9 Other Components Lead Time 7-23
7-10 New Engine Valve Facility Lead Time 7-24
8-1 Production Equipment Manufactuers' Overall Lead Time 8-2
8-2 Engine Block Machine Transfer Line 8-3
8-3 Automatic Transfer Line Lead Time 8-4
8-4 Transfer Line - Representative Lead Time (Cylinder Head Machining) 8-7
8-5 Underdrive Press 8-9
8-6 Cold Stamping Press Lead Time 8-12
8-7 Nonvacuum Machine for Electron Beam Welding 8-15
8-8 Electron Beam Welders 8-16
8-9 Production Line Welders Overall Lead Time 8-17
8-10 Electron Beam Welder Compressed Lead Time Order for Six Welders for General Motors Catalyst Container 8-20
9-1 Westinghouse Critical Path Network 9-4
9-2 Westinghouse Refrigerator Evaporator Relocation . . . 9-5
9-3 General Electric P-7 Self-cleaning Oven Program . . . 9-8
9-4 Outboard Marine Lead Time Schedule for 1973 Model Year Engine 9-11
9-5 Outboard Marine Lead Time Schedule for 1973 Rotary Combustion 35-Horsepower Snowmobile Engine (Wankel) 9-13
10-1 Military Vehicle Procurement Lead Time 10-4
11-1 Projected Platinum Usage 11-15

TABLES

VOLUME II

2-1 Phase Activities and Schedule Milestones 2-5

4-1 Lead Time Tradeoffs--Automation versus Manual Assembly 4-6

5-1 Chrysler Emission Control Modifications for 1970 through 1975 Model Year Production 5-51

6-1 Catalyst Suppliers and Products 6-5

6-2 Substrate Suppliers and Products 6-6

6-3 Current and Pending Contract Agreements--Oxidation Catalysts and Substrates 6-14

6-4 Corning W-1 Monolithic Substrate Nominal Properties 6-33

6-5 Grace Major Schedule Milestones 6-50

6-6 Matthey Bishop Quality Control Tests 6-76

6-7 Monsanto Projected Equipment and Material Lead Time Requirements 6-85

6-8 Oxy-Catalyst Plant Construction Milestones 6-93

6-9 Reynolds Proposed Specifications for Experimental Alumina Supports, 6 x 8 Mesh; Nominal 0.100 in. Diameter 6-100

6-10 UOP Catalyst Plant Floor Area Requirements 6-109

11-1 World Production of Noble Metals 11-3

11-2 Estimated Noble Metal Composition 11-3

11-3 Estimated Noble Metal Reserves in the World 11-6

TABLES (Continued)

VOLUME II

11-4 Estimated 1972 Capacity and Production of South African Noble Metal Mines 11-7

11-5 Projected Maximum Noble Metal Production Capacity of South African Mines 11-7

11-6 Rustenburg Platinum Quantities Potentially Available to the Automotive Industry (excluding Ford) 11-9

11-7 Projected 1975 Model Year Vehicle Distribution 11-11

11-8 Predicted Automotive Noble Metal Requirements for 1975 Model Year Vehicles 11-12

11-9 Predicted Total Automotive Noble Metal Requirements for 1975 11-13

11-10 Projected Automotive Platinum Requirements 11-14

11-11 Projected Noble Metal Supply and Demand 11-17

11-12 Rustenburg Free World Platinum Supply and Demand Projection 11-19

11-13 Noble Metal and Platinum Supply — Automotive Demand Balance 11-20

SECTION 1

INTRODUCTION

This report presents an assessment of available information pertaining to the production lead time requirements of the domestic automotive industry for 1975/76 model year automobiles. As used herein, the term production lead time refers to the time allocated by the automobile manufacturer to develop or acquire the facilities and equipment needed for the production of a future model year product line. For purposes of this study, the production lead time is referenced to the interval of time between the commitment of major resources to a program and the point at which the first mass produced automobile comes off the assembly line.

To fulfill the objectives of this study, the work effort was divided into two basic areas. In one area a compilation was made of all information available from four sources: (a) the manufacturers' applications for suspension of the 1975 emission standards, (b) the testimony and supplementary material presented by witnesses at the April 10-28, 1972 EPA Suspension Request Hearings, (c) an open literature survey, and (d) visits to automotive industry and related sources for technical discussions of relevant production lead time factors. In the other area, a review, summarization, and evaluation of all data acquired were performed.

Included in this study were the lead time requirements of the major automobile manufacturers, catalyst and substrate manufacturers, automotive component manufacturers, production equipment manufacturers, nonautomotive industry manufacturers, and a government automotive procurement agency. Emphasis has been directed toward identifying critical lead time components and subsystems associated with the introduction of emission control systems required to meet the 1975/76 emission standards -- in particular, catalytic converters. In addition, associated lead time requirements were evaluated for new or expanded facilities, tooling commitments, orders for raw or processed materials, system durability testing, prototype test programs, and certification test programs.

The body of the report is based primarily on the most recent information obtained by visits to automotive and nonautomotive industry manufacturers for technical discussions of critical production lead time factors. Also contained in the report is an assessment of platinum-group metal production and usage. Appendix A contains a complete listing of the companies visited.

Although the study was principally oriented toward current conditions in industry efforts to meet government regulations for exhaust emissions of 1975 and 1976 light-duty vehicles, the information developed in regard to traditional component and equipment manufacturers is sufficiently general in presentation as to constitute a basis of reference for any future studies.

Additional industry efforts to meet other government regulations (e.g., safety regulations) were not addressed.

SECTION 2

AUTOMOTIVE PRODUCT DEVELOPMENT PHASES

2.1 INTRODUCTION

The process of developing an automotive product from concept to mass production can be viewed as proceeding in discrete phases. These phases, though highly interrelated and in some instances overlapping in time, may be isolated and characterized in terms of specific activities and operations. It is the purpose of this section to describe these developmental stages and in so doing to introduce and define the basic terminology used throughout this report.

2.2 FUNDAMENTAL DEFINITIONS

It is useful at the outset to underscore the fact that the term "lead time" is a generic phrase that can be (and is) applied to any one of a number of different processes in the automotive development cycle. In its broadest sense, lead time is simply the time allocated or required to accomplish a given set of operations or functions. Thus, to cite a few examples, there is a lead time for car body styling, for production process design, and for the fabrication or procurement of production machinery and equipment. Furthermore, the terminology is commonly applied at different levels of the automotive chain of supply. For example, the fabricator of machine tool equipment for the automobile manufacturer has a scheduled lead time for procuring mill-forged press components or vendor-supplied electrical controls, in addition to the lead time required for machine parts fabrication and assembly within his own shop.

Two specific terms involving lead time may now be advanced and defined: product development lead time and production lead time. Product development lead time is the total time required for the development of the automotive product, starting from the initial formulation of the design concept and ending with Vehicle Job No. 1, the first of the production run of automobiles of a model year off the assembly line. Production lead time is the designation for that part of product development lead time which encompasses activities concerned with the development of mass manufacturing techniques. Specifically, production lead time is defined as the time reserved by the automobile manufacturer to (a) detail the product configuration for mass manufacture; (b) analyze the manufacturing processes; (c) design or plan the equipment and facilities needed to perform these processes; (d) erect facilities and construct, install, and check out the production equipment; and (e) escalate the manufacturing process to full volume output.

As defined above, production lead time activities may consume 95% of the resources spent in a car development program. The following overview of the product development cycle will serve to provide a suitable framework within which these activities may be examined in more detail.

2.3 PRODUCT DEVELOPMENT CYCLE OVERVIEW

For purposes of this discussion the automotive product development cycle should not be viewed in terms of the action required to produce any given model in any given year. In the aggregate of products offered by the manufacturer, one or more car lines may undergo substantial changes in the design of functional systems or body structure. In other lines, which do not undergo major modifications, a substantial percentage of component parts may be newly designed. Regardless of the degree of change from the previous model, however, the car development proceeds according to a planned cycle of events which is common for all lines being introduced into production.

A representative product development cycle may be considered to consist of eight different phases:

Research and Advanced Development
Product Conceptualization
Concept Development/Vehicle Preliminary Design
Car Program Approval

Production Engineering/Car Prototype Testing
Parts Procurement/Tool Construction, Installation, and Tryout
Pilot Assembly
Production Buildup

The timing and typical duration of these phases are illustrated in Figure 2-1. It is noted that the data shown are broadly representative of practice throughout the automotive industry; however, specific details in any given manufacturer's schedule may differ considerably from these values.

Referring to Figure 2-1, the schedule for Research and Advanced Development is unbounded because of the broad range of possible durations associated with new invention activity. This phase, though not strictly part of a car development program, is regarded by the industry as an essential prerequisite to the introduction of new functional components or features in a vehicle. Durations as long as 5 to 10 years appear to be possible.

Excluding Research and Advanced Development, the overall product development cycle has a duration of approximately 48 months. The milestone marker shown in the chart identifies the point selected as the Production Lead Time reference, representing the start of significant activity on the development of mass production processes and facilities. The indicated lead time to Vehicle Job No. 1 is 26 months; historical data from individual manufacturers indicate a range from 24 to 28 months (Ref. 2-1).

Details of the individual phases of the product development cycle are presented in the following paragraphs and in Table 2-1, which shows typical phase activities and significant schedule milestones.

2.4 PRODUCT DEVELOPMENT PHASES

2.4.1 Research and Advanced Development

Normally, every major automotive innovation undergoes a period of research, experimental development, and testing before being introduced to production. As mentioned earlier, the Research and Advanced Development phase can precede a car development program by as much as

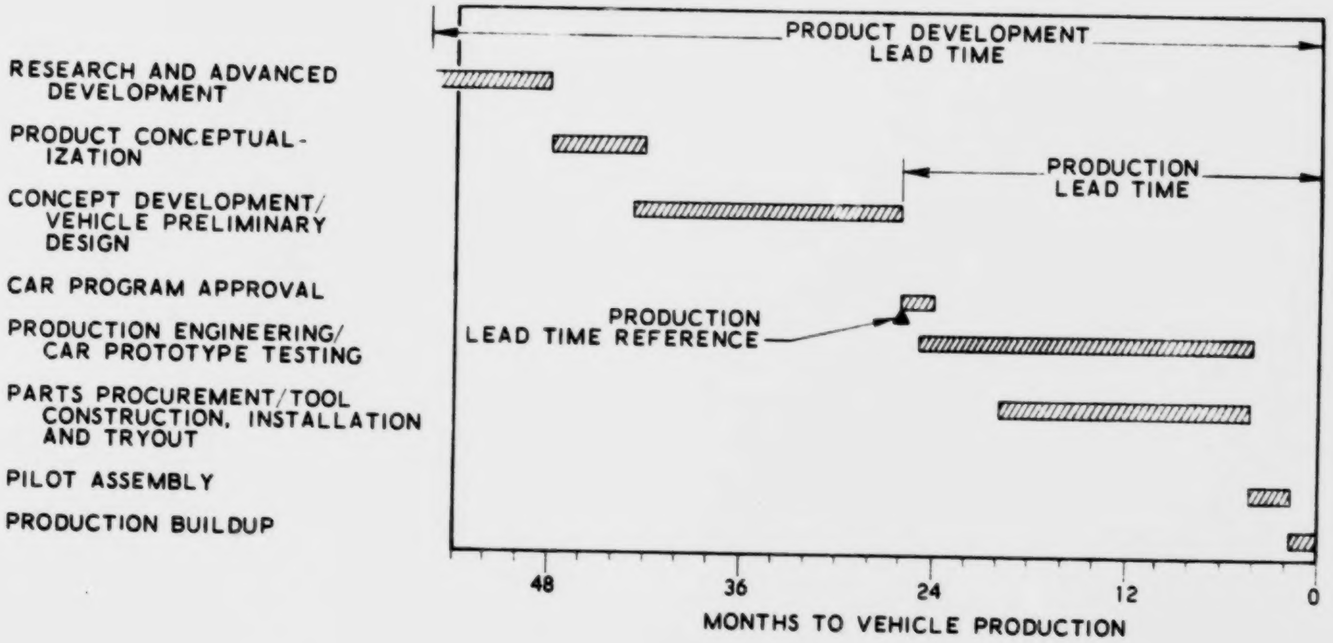


Figure 2-1. Automotive Product Development Phases

Table 2-1. Phase Activities and Schedule Milestones

Phases	Typical Activities	Significant Milestones
Research and Advanced Development	Invention Proof-of-Principle Testing Research Prototype Testing	Research Hardware Build Feasibility Demonstration
Product Conceptualization	Options Identification Alternate Design Evaluation	Tentative Car Line Proposal Definition
Concept Development/Vehicle Preliminary Design	Car Line Proposal Reviews Cost/Producibility Studies Interface/Interaction Studies Car Systems Selection Mechanical Prototype Design	Car Plan Selection Long Lead Time Facilities Commitment
Car Program Approval	Commitment of Program Resources	Production Design Preliminary Approval
Production Engineering/Car Prototype Testing	Mfg Process Analysis & Decisions Tooling Design & Commitment Detail Drawings & Release Systems/Vehicle Testing	Tooling & Facilities Approval Clay Model Approval Drawing Release EPA Certification Tests
Parts Procurement/Tool Construction, Installation, and Tryout	Make/Procure All Parts Install & Test Production Equipment	Parts/Equipment Contracts Complete Tool Tryout Build/Submit Last Samples
Pilot Assembly	Volume Test Production Process	Start Pilot Part Program
Production Buildup	Accelerate Operations to Full Rate	Full Component Production Start Vehicle Production

5 to 10 years. For example, the energy-absorbing, or collapsible, steering column underwent a 6-year period of development before being put into production (Ref. 2-1).

In this phase, the new device or invention is subjected to a variety of basic proof-of-principle tests, followed by experimental prototype development and demonstration tests. The experimental prototype incorporates the functional features of the new invention in a (hand-built) preliminary-concept version of the production hardware configuration. The platform adapted for test purposes usually consists of an existing vehicle, modified as required to accommodate the new device at its interfaces with other vehicle components. The test program may continue for an indefinite period; several designs or design modifications may evolve before a suitable configuration is achieved. At this point, the new device would be turned over to a car program advanced engineering group for refinement, modification into a design suitable for mass production, and additional testing.

Frequently, the new device or modification is introduced on a single model as a limited production, low volume option for a period of evaluation in customer use before it is adopted for use throughout a car line or in several car lines. To cite an example of this practice, disc brakes were first introduced in the United States on the Chevrolet Corvette; they are now available as standard or optional equipment on 60% of domestic automobile production (Ref. 2-2).

It is noted that the current effort by the automotive industry with respect to the accelerated introduction of catalytic converter emission control systems on all 1975 model year vehicles is in sharp contrast with the conventional procedures described above.

2.4.2 Product Conceptualization

The first few months preceding the initiation of a car line program is spent in styling, engineering, and product planning activities which explore the alternative approaches to the design and appearance of the new model. The factors shaping the selection of these alternatives include the status of research and advanced development projects, manufacturing costs, competitive pressures, and the projected market for the features and options under consideration. Potential modifications and improvements are delineated, and from the alternatives available tentative proposals for each car line are selected for presentation to management. This phase may have a duration of 6 months, as indicated in Figure 2-1.

It should be noted that experimental testing of new car systems begun earlier may continue throughout this phase and succeeding phases. The extent of such testing is dependent on the need for continued development of safety devices or emission control equipment required to meet standards imposed by statutory regulations targeted to a given model year. Normally at this juncture, new functional features that are imperfectly developed or which would involve excessive cost penalties to incorporate are deferred to subsequent model year production programs, in contrast to vehicle image features which are seldom if ever deferred because of incomplete development.

2.4.3 Concept Development/Vehicle Preliminary Design

In the beginning months of this phase, which for several manufacturers begins at about 43 months prior to Vehicle Job No. 1, the available alternatives and tentative proposals for the individual car lines are reviewed and an overall package plan for each line is selected. At this point, the broad objectives for the car development program are established, including such factors as the number of models to be offered, performance levels sought, budget to be assigned, equipment to be included, overall size and weight, styling goals, and seating capacity. Cost tradeoffs, technical feasibility studies, and producibility investigations are carried out; interface/interaction studies involving chassis, body, and power train are performed; and facility requirements are checked against available resources. Changes to the initial assumptions are made as required for compatibility among all of the program objectives. Procurement activities related to long lead time facilities acquisition may be initiated in this period.

Vehicle design studies begin: Body styling, space envelope definition, and occupant packaging are initiated; full size clay models are developed. Exterior and interior dimensions of the vehicle are defined. Driveline, chassis, and engine compartment dimensions are finalized. Body structure, instrument panels, and front compartment designs are completed. Emission devices/systems are selected.

Vehicle testing and modification of new car systems (e.g., emission control systems) will continue throughout this phase if required (see, for example, Ford Motor Company's 5-vehicle experimental durability test fleet and Riverside test fleet programs discussed in Section 5.2).

2.4.4 Car Program Approval

The car system selection/preliminary design effort described earlier undergoes management review and approval on a periodic basis. Final management review of the entire car program package, now finalized in terms of performance characteristics, features, equipment, and appearance, occurs at about the 26-month period. This phase may last from 1 to 1-1/2 months.

The program approval phase is a key point in the product development cycle for two significant reasons. One of these is that, in a normal development program, it fixes the key parameters and specifications in the vehicle design which form the basis for much of the technical effort which follows. The other reason is that it signals the commitment of major program funds. Up to this point, perhaps 5% of the total program resources are utilized; the balance is expended in the remaining 26 months before production, primarily on facilities, major items of equipment, tooling, and parts and material procurement.

Because of the surge of activity and resource expenditures on production-oriented functions which begin at or immediately after this point, the program approval milestone will be used at various times in this report as a convenient reference point for the identification of the production lead time requirement, most frequently in reference to the major automobile manufacturer (the lead time for the supplier of parts or equipment generally is referenced to a contractual commitment from the automobile manufacturer). It should be recognized, however, that the various phases of the product development cycle overlap. Accordingly, some initial capital commitments and some manufacturing operations may begin as soon as a probable design has been identified.

2.4.5 Production Engineering/Car Prototype Testing

After Program Approval, the next major phase of activity that may be delineated is the Production Engineering/Car Prototype Testing phase which has a duration of 21 months (Figure 2-1). Within the interval indicated, sustained peak-level production engineering activity may have a duration of about 12 months. Car testing activities may start prior to the initial release of detailed production drawings and may continue some months after final engineering drawing release.

Production engineering involves all of the process engineering and parts design operations required to convert the complete car program package plan into mass produced and assembled components and subsystems. Manufacturing processes and techniques are investigated and the details of the manufacturing and assembly operations and material and parts flow are delineated. Part and assembly drawings are detailed; facilities, plant layout, equipment, and tooling requirements are defined. These are submitted for management approval and subsequent release to manufacturing development or to purchasing for procurement. In this period, the full scale clay of the vehicle is approved and die patterns for the body panels are constructed.

Testing operations in this phase fall into three categories: mechanical prototype tests, engineering prototype tests, and EPA certification tests. The mechanical prototype is a vehicle test bed that utilizes an existing body structure to test the frame, underbody, power train, suspension, brake, and other systems planned for the production vehicle. Design of these parts and functional systems may start several months before Car Program Approval. Mechanical prototype testing may include hot weather, altitude, performance, economy, and other road tests as well as laboratory tests. Several mechanical prototype series vehicles may be built, incorporating successive refinements in subsystem design until production level versions are evolved.

Engineering prototype vehicles are totally representative of the final car product. The engineering prototype is used to test sheet metal and structural features of the final design, as well as to continue the test and development of mechanical features. The test program is comprehensive, encompassing all of the conditions expected to be met in customer operation, including rough road, city traffic, high altitude, etc.

The EPA certification tests involve two groups of vehicles: emission data (4000-mile) vehicles, involving as many as four cars per engine family, and durability data (50,000-mile) vehicles, one per engine family. The durability test fleet (which is assembled and tested first) and the emission data vehicles are constructed from hardware similar in all material respects to production vehicles. The certification test procedure involves road mileage accumulation on a prescribed (modified AMA) duty cycle with dynamometer tests of emissions at 4000 miles (emission data vehicles) and at successive 4000-mile intervals up to 50,000 miles (durability data vehicles).

Durability testing for 1975 vehicles is scheduled by the various manufacturers to start in the September/October period of 1973 (11/10 months before Vehicle Job No. 1), and to continue for about 6 months. Testing of emission data vehicles is scheduled to start in the period from November 1973 to March 1974 and may involve durations of from 2 to 4 months, depending upon the extent of required modification and retesting encountered.

2.4.6 Parts Procurement/Tool Construction, Installation, and Tryout

The activities accomplished in the Parts Procurement/Tool Construction and Installation phase may encompass the detailing of process or parts specifications; the preparation of requests for vendor quotes; the selection of suppliers and fabricators; and the operations of design, construction, and installation of process machinery, equipment, and tools fabricated in house or by selected vendors. Some automobile manufacturers have a substantial in-house tooling capability; others do not. As indicated in Figure 2-1, this phase may overlap considerably the Production Engineering/Car Prototype Testing phase discussed in the previous subsection. A duration of 12 to 16 months is possible; the longer duration has been selected for illustration in Figure 2-1.

Decisions to buy, as opposed to making, a part are generally accomplished in the Production Engineering phase on the basis of the combined judgment of engineering, purchasing, cost estimating, manufacturing, and, in some instances, outside vendor consultations. Those parts having the longest procurement or longest tooling construction lead times are detailed first for release. Sufficient lead time must be provided for vendor capital equipment procurement and facilities construction requirements, as typified by the needs associated with catalytic converter production for 1975 automobiles (see Section 6).

With regard to production equipment, the long lead time items, typically, are the large, assembly-line process equipment pieces such as transfer lines for automatic sequential machining operations and high-capacity, multiple-action presses for cold metal working operations (forming, blanking, piercing, etc.). Lead time for these machines from receipt of order to installation and checkout may range from 14 to 16 months in the case of transfer lines, and from 7 to 11 months in the case of presses. Other specialized devices, such as the General Motors Corporation electron beam welding equipment, may involve considerably longer lead times.

Checkout of specialized machinery such as discussed above is first accomplished at the vendor facility. A number of pieces are produced and examined for compliance with parts specifications. Then, the equipment is disassembled and shipped and re-erected and rechecked at the automotive assembly plant. Installation times for these large pieces of equipment may range from 3 to 6 weeks; initial tryout after installation may involve another 3 to 6 weeks. To these specialized equipment items must be mated jigs, fixtures, conveyor equipment, and other assembly apparatus.

2.4.7 Pilot Assembly

The objectives of Pilot Assembly are to identify and correct basic problems in the fabrication and assembly processes. This phase may have a duration of from 2 to 4 months; a 3-month interval is selected for display in Figure 2-1.

Typically, machinery and tooling set up and tryout operations at supplier facilities and at the automotive plants are completed about 4 months prior to Vehicle Job No. 1. First piece or sample parts made from production tooling are checked against detailed part drawings, templates, and specifications and then approved. These production samples are made available to the automotive assembly plant for check of functional fit and performance in a vehicle sample assembly. Necessary modifications to tooling and equipment are made in this period.

Following this, one or more pilot assembly runs are made to check out the volume fabrication and assembly processes. Several run attempts may be necessary, depending on the modification requirements exposed as sustained production trials are attempted.

2.4.8 Production Buildup

A 1-1/2-month interval is assigned to the Production Buildup phase. By the beginning of this interval, vendors and part suppliers have completed their initial production runs and parts are made available in the automotive assembly plants to start stocking the production line. In this period, component production at the automotive plant facilities is accelerated toward full volume output rates. For example, engine production and other subassembly production will be started in advance with a target date for first production output 1-month earlier than Vehicle Job No. 1, the first vehicle produced on the mass production assembly facility. All of this stockpiling for inventory will precede the production buildup of the vehicle assembly line which will generally commence in the last few weeks of this period.

REFERENCES

2-1 Automotive Industrial Engineering Study, Arthur Young & Company (January, 1968).

2-2 Automotive Industries (March 15, 1972).

SECTION 3

PROPOSED 1975/76 MODEL YEAR AUTOMOBILE EMISSION CONTROL SYSTEMS

3.1 INTRODUCTION

In this section of the report, a brief discussion is presented of the emission control systems and system components proposed by the major domestic automobile manufacturers for use in their 1975/76 light-duty vehicles. More detailed information regarding automotive emission control system technology and characteristics can be found in Refs. 3-1 to 3-3.

3.2 PROJECTED 1975/76 EMISSION CONTROL SYSTEMS

3.2.1 Summary Discussion

The 1975 emission control system is exemplified by the following package of components and engine modifications:

Oxidation catalytic converter
Air injection
Partial thermal reactor
Exhaust gas recirculation (EGR)
Carburetor modifications
Ignition system modifications

All first-choice systems selected by the domestic automobile manufacturers incorporate an oxidation catalyst with air injection to promote the oxidation of the unburned hydrocarbon (HC) and carbon monoxide (CO) species contained in the engine exhaust. The catalyst type which appears most frequently among the selected first-choice systems is the platinum-group metal/monolithic converter. Base metal/pelletized and promoted base metal/pelletized catalyst designs[1] also are being evaluated by some manufacturers, including the General Motors Corporation and the American Motors Corporation. Some automobile manufacturers are considering the utilization of a catalyst overtemperature protection device in their projected 1975 systems to prevent catalyst damage under extreme/abnormal engine operating conditions (spark plug misfire, etc.)

---

[1] Promoted base metal catalyst formulations contain small amounts of platinum-group metals.

Exhaust gas recirculation (EGR) systems will be employed in nearly all of the 1975 model year automobiles. These systems will be improved versions of the EGR systems used in most of the 1973 model year vehicles.

The emission control systems of a number of manufacturers, including those of the Chrysler Corporation, Ford Motor Company, and General Motors, utilize a partial thermal reactor in place of the conventional exhaust manifold primarily to provide more rapid warmup of the catalyst under cold start conditions. However, full size thermal reactors are not completely developed and are not being considered for 1975 systems.

Carburetion/intake system modifications that have been identified for first-choice systems range from complete redesigns, utilizing new concepts, to minor improvements to the current conventional systems. These modifications are generally directed toward improving the precision and stability of the air-fuel ratio and also include such features as altitude compensation, quick-release choke devices, and intake manifold heating.

All domestic manufacturers propose, or have in development, electronic (breakerless) ignition systems which are targeted for inclusion in their first-choice emission control system. These systems generally provide an improvement in spark-timing precision, consistency, and reliability.

Alternate systems under investigation by the automobile manufacturers for potential use in 1975 model year vehicles incorporate different types or designs of catalytic converters but are otherwise similar to the emission control packages selected as first-choice systems. Typical examples are the second- and third-choice systems of General Motors which substitute platinum-group metal pellet and platinum-group metal monolithic converter designs for the first-choice promoted base metal/pellet converter design.

At least two manufacturers, Ford and General Motors, are experimenting with full size thermal reactors for potential use in emission control systems. For instance, Ford utilizes full-size thermal reactors in conjunction with dual (in series) platinum-group metal/monolithic catalysts and EGR in some of its durability experimental test vehicles. Development work on these systems is still incomplete and lags behind the effort directed at catalytic converter systems.

Emission control systems currently under consideration by the automobile manufacturers for use in 1976 model year vehicles will incorporate all components in the 1975 system plus:

Reduction catalyst(s) installed upstream of the oxidation catalyst(s)
More sophisticated air injection systems
Modified carburetion, ignition, and EGR systems

A number of automobile manufacturers are experimenting with unconventional engine configurations, including the rotary (Wankel), stratified charge, gas turbine, Rankine, and Stirling engines. With the exception of the rotary engine, which might be utilized in some of the domestic 1975/76 vehicle models, it appears that these unconventional engines will be neither developed nor be manufacturable in large quantities in time for the 1975/76 model year. Therefore, these engines are not considered in this study.

3.2.2 Selected Emission Control Systems – By Manufacturer

3.2.2.1 American Motors

American Motors first-choice 1975 system includes an oxidation catalytic converter, EGR, secondary air injection, and extensive engine modifications. A final decision has not been made as to whether the catalytic converter will be a platinum-group metal monolithic type or a base metal or promoted base metal pelletized type. Designs which appear to be prime candidates are the Engelhard Minerals and Chemicals Corporation platinum-group metal system and the General Motors base metal (or promoted base metal) system. The projected engine modifications include changes in the carburetion and induction systems, valve timing, cylinder head design, ignition system, and combustion chamber configuration.

American Motors does not have an alternate 1975 system. It believes the first-choice system is the only approach which has any chance for success and that exploring alternative or second-choice systems would dilute its primary effort.

To date, American Motors has provided no information on its projected emission control system for 1976.

3.2.2.2 Chrysler

Chrysler's first-choice 1975 emission control system, shown schematically in Figure 3-1, incorporates a platinum-group metal monolithic oxidation catalytic converter, EGR, exhaust port air injection, a catalyst bypass protection system, a partial exhaust thermal reactor, and improved carburetion and ignition systems.

The selection of the monolithic catalytic converter was based on the success achieved with this device in meeting the 1975 standards under zero-mileage laboratory conditions. The monolithic platinum-group metal converter design was preferentially selected over pelletized systems on the basis of Chrysler's experience that the platinum-group metal monolith had higher activity at the lower engine temperatures. Also, Chrysler's early development work with pebble-bed catalysts showed pronounced deterioration problems. A double-wall exhaust pipe may be included in the Chrysler system to minimize the heat loss between the thermal reactor and the catalytic converter.

Second-choice systems being pursued by Chrysler include the use of a pellet-type converter such as the Universal Oil Products Company (UOP) stabilized spherical platinum catalyst. Other possible modifications to the first-choice system include (a) deletion of the 30% thermal reactor and of

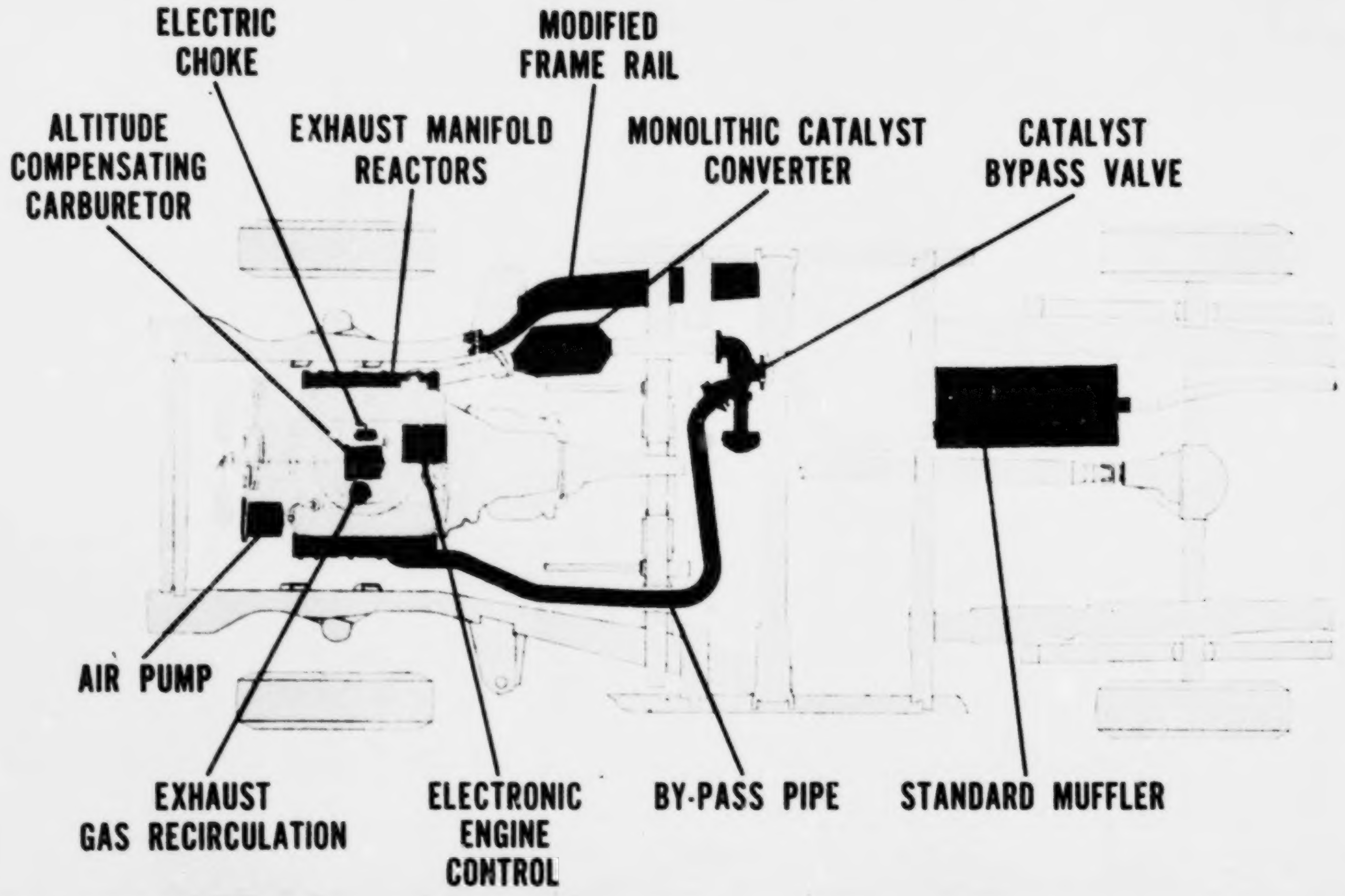

ELECTRIC CHOKE
MODIFIED FRAME RAIL
ALTITUDE COMPENSATING CARBURETOR
EXHAUST MANIFOLD REACTORS
MONOLITHIC CATALYST CONVERTER
CATALYST BYPASS VALVE
AIR PUMP
EXHAUST GAS RECIRCULATION
ELECTRONIC ENGINE CONTROL
BY-PASS PIPE
STANDARD MUFFLER

Figure 3-1. Chrysler A-335 Special Emission Car (System Features)

the double-wall exhaust pipe (provided that cold start emissions can be brought within manageable limits), and (b) elimination of the catalyst bypass system (provided that better exhaust gas temperature control is achieved or more tolerant catalysts are found).

The major efforts to meet the 1976 emission standards are directed at the development of a dual-bed catalyst system consisting of a thermal manifold reactor with air injection during warmup, followed by a reduction catalyst, air injection, and an oxidation catalyst. EGR may be required also to meet the low 1976 nitrogen oxides (NO_x) standard.

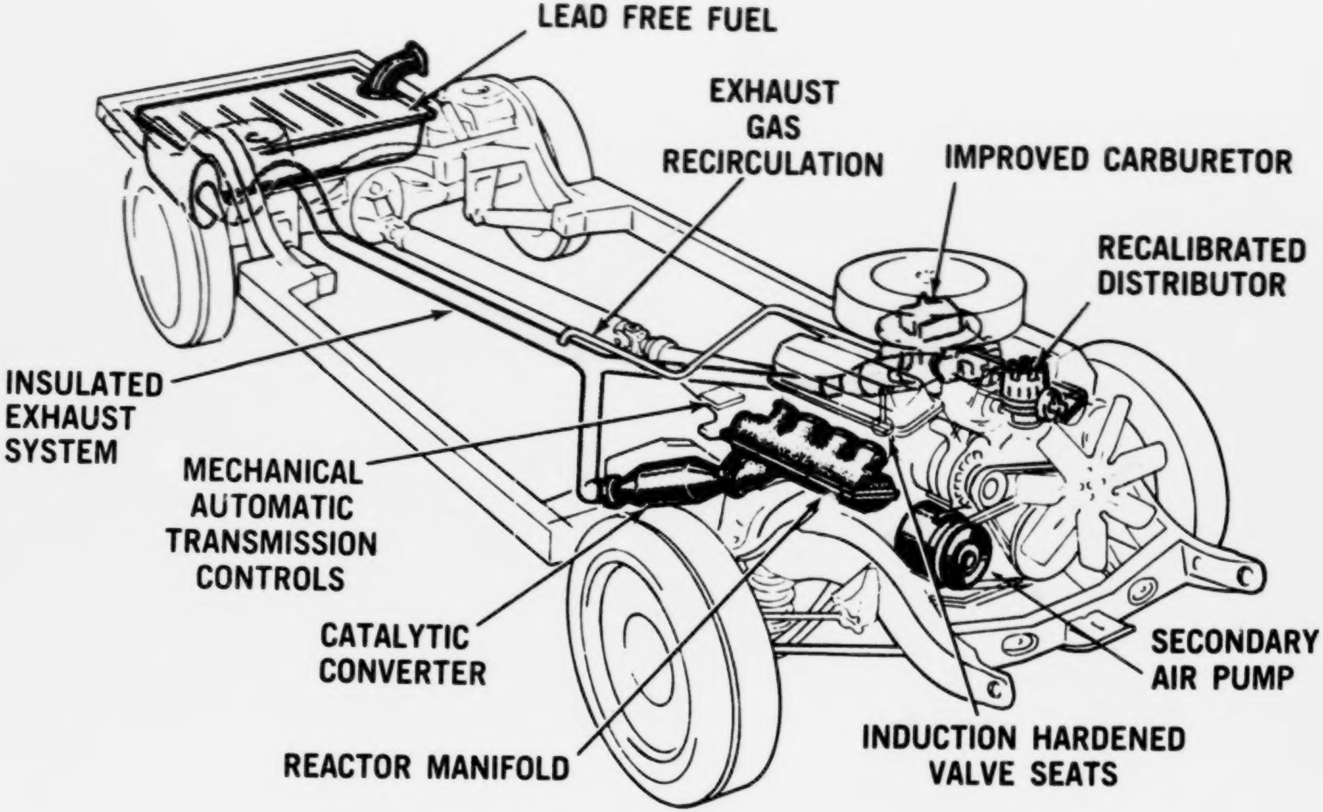
3.2.2.3 Ford

Based upon currently available data, it is Ford's judgment that its first-choice system for 1975 will consist of an oxidation catalytic converter in conjunction with EGR, secondary air injection, and engine modifications. This system is undergoing durability testing at Riverside, California. Also, two other systems are being tested there by Ford. These systems include dual catalysts with thermal reactor, and dual catalysts without thermal reactor.

Currently, the single catalyst system seems best, considering that it has minimum impact on the design of the vehicle front end, requires less platinum than the dual catalyst systems, and is equally effective in terms of emission control as the two other systems tested. Ford feels that the prospects are good for further improvements of this system.

A single Engelhard PTX-type catalytic converter will be used on Ford's 4-cylinder and 6-cylinder passenger cars and the V-8, F-100 pickup truck. Two catalysts, one on either side, will be used on the V-8 engine passenger cars. This "kitchen sink" system is illustrated in Figure 3-2.

For 1976, the Ford kitchen sink system continues to be the principal candidate. In this system, reduced NO_x levels are sought by means of higher EGR flow rates and incorporation of a reduction catalyst. Ford is also working on a dual-bed (reduction-oxidation) catalyst system and on two advanced engine concepts (PROCO and lean-burn engines).


LEAD FREE FUEL
EXHAUST GAS RECIRCULATION
IMPROVED CARBURETOR
RECALIBRATED DISTRIBUTOR
INSULATED EXHAUST SYSTEM
MECHANICAL AUTOMATIC TRANSMISSION CONTROLS
CATALYTIC CONVERTER
SECONDARY AIR PUMP
REACTOR MANIFOLD
INDUCTION HARDENED VALVE SEATS

NOTE: THE 1976 (76-1) EMISSION SYSTEM WILL USE 1975 SYSTEM COMPONENTS BUT WILL BE TOTALLY RECALIBRATED FOR NOx REDUCTIONS.

Figure 3-2. Ford 1975 "Kitchen Sink" Emission Control System

3.2.2.4 General Motors

Two first-choice emission control systems are currently being considered by General Motors for potential application in their 1975/76 model year vehicles. These systems are illustrated in Figures 3-3 and 3-4.

The under-floor system, shown in Figure 3-3, currently is General Motors preferred system for 1975. It consists of a pellet-type, promoted base metal oxidation catalytic converter, secondary air supply, EGR, and engine modifications. This system is similar to the system described by General Motors at the April 1972 EPA Suspension Request Hearings, except that it no longer includes all-base-metal catalysts. The projected promoted base metal catalyst formulations contain small amounts of platinum and/or palladium. The engine modifications used in this system include an improved carburetor with altitude compensation and fast-acting choke, a redesigned intake system with quick-heat manifold to produce early fuel evaporation (EFE), an exhaust system acting as a partial thermal reactor, an electronic ignition system, and a modified spark timing schedule.

For 1976, General Motors is considering the addition of a reduction (NO_x) catalyst to their under-floor system. During the engine cold start period, secondary air will be added upstream of the reduction catalyst in order to accelerate catalyst warmup.

The triple-mode system, shown in Figure 3-4, is another first-choice system. This system, recently announced by General Motors, is basically a 1976 system. It incorporates the system components and engine modifications used on the under-floor system and a cylindrical monolithic catalytic converter which is cast into the engine exhaust manifold. The center part of the monolith provides the reduction catalyst and the outer part the oxidation catalyst. The system operates in three separate modes. In the startup mode, illustrated in Figure 3-4, exhaust gas from the quick-heat manifold enters the reduction catalyst which is initially operated as an oxidation catalyst to provide rapid catalyst warmup. During normal vehicle operation, the catalyst is used in the reduction-oxidation mode and secondary air is injected at the exit of the reduction catalyst. During high-speed and high-load conditions,

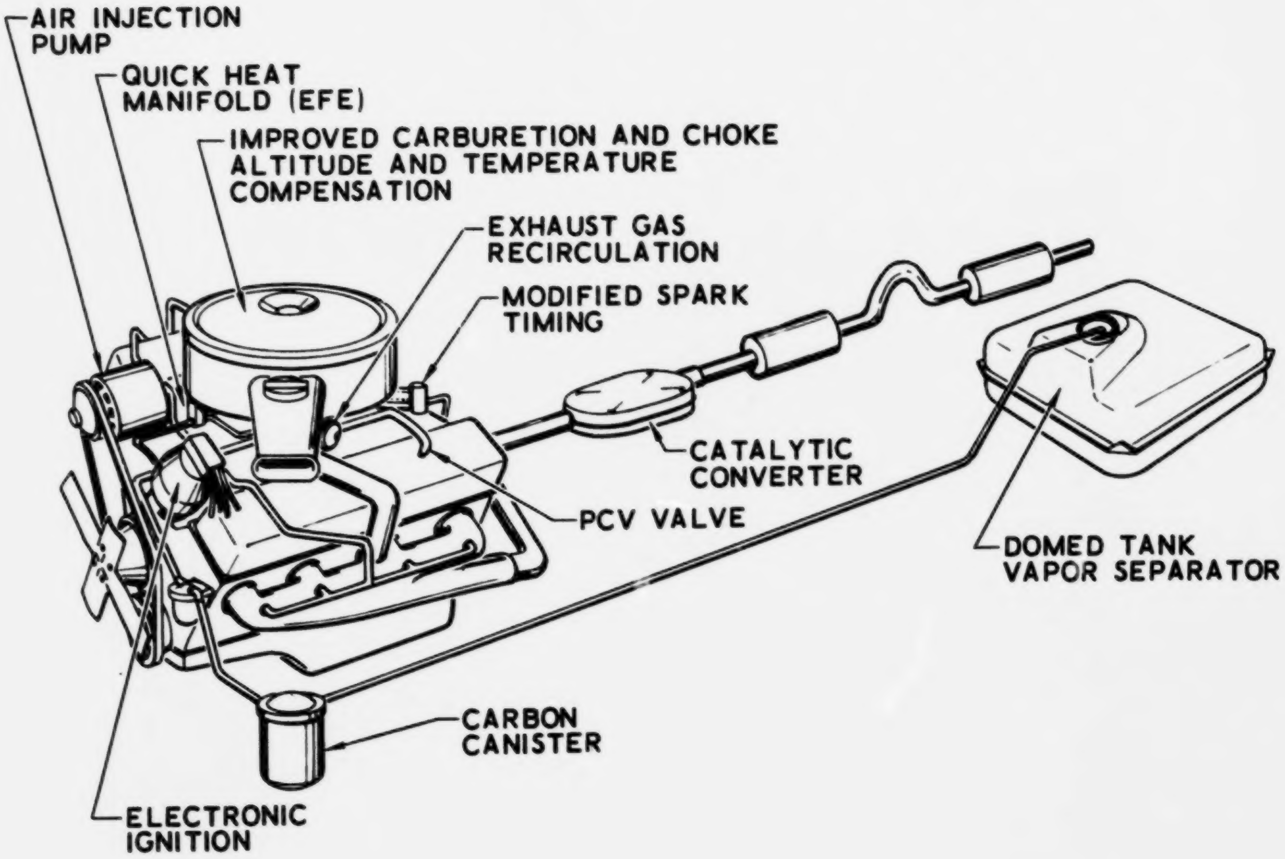

AIR INJECTION PUMP
QUICK HEAT MANIFOLD (EFE)
IMPROVED CARBURETION AND CHOKE ALTITUDE AND TEMPERATURE COMPENSATION
EXHAUST GAS RECIRCULATION
MODIFIED SPARK TIMING
CATALYTIC CONVERTER
PCV VALVE
DOMED TANK VAPOR SEPARATOR
CARBON CANISTER
ELECTRONIC IGNITION

Figure 3-3. General Motors Projected 1975 Under-Floor Emission Control System

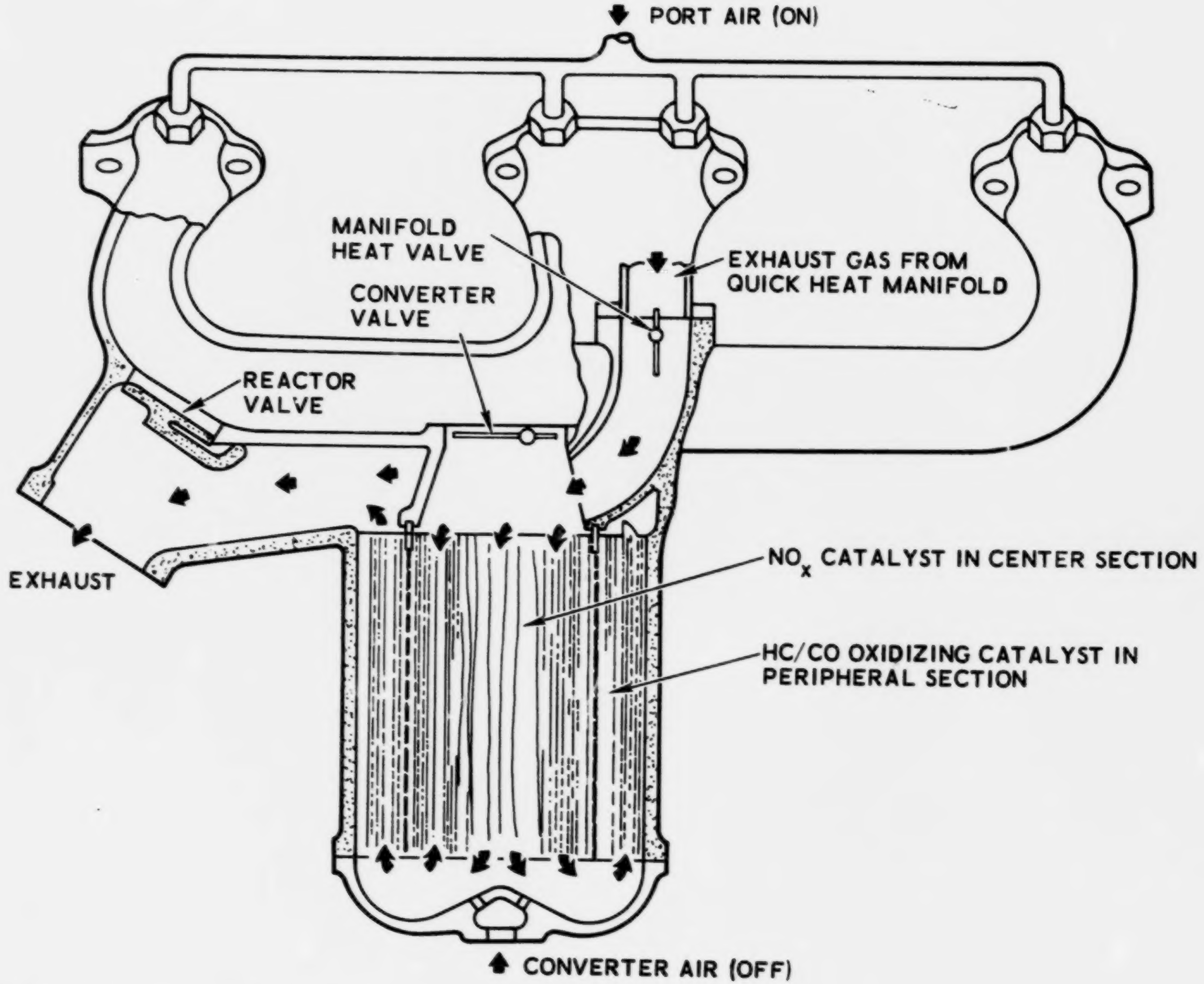

PORT AIR (ON)
MANIFOLD
HEAT VALVE
EXHAUST GAS FROM
QUICK HEAT MANIFOLD
CONVERTER
VALVE
REACTOR
VALVE
EXHAUST
NO_x CATALYST IN CENTER SECTION
HC/CO OXIDIZING CATALYST IN
PERIPHERAL SECTION
CONVERTER AIR (OFF)

Figure 3-4. General Motors Triple-Mode Emission Control System (T-MECS) – Catalytic Converter (Startup Oxidizing Mode)

the catalysts are bypassed (for protection) and the system operates then in the thermal reactor mode. This system can be converted very easily to a 1975 system by deleting the reduction catalyst.

Alternate emission control systems being evaluated by General Motors include platinum-group metal/pellet and platinum-group metal/monolithic catalytic converters. Another alternate system utilizes a thermal reactor for some vehicles like the Vega (4-cylinder engine). Air-fuel conditions required for reactor operation offer the advantage of less initial release of NO_x, thereby lessening the aftertreatment requirement by the reduction catalyst systems planned for 1976.

Based on current General Motors experience, it appears that the only promising approach for 1976 is the addition of a reduction catalyst to the 1975 systems.

REFERENCES

3-1. Final Report - "Status of Industry Progress Towards Achievement of the 1975 Federal Emission Standards for Light-Duty Vehicles," Aerospace Corporation Report No. ATR-73(7322)-1, 28 July 1972

3-2. "Automobile Emission Control - A Technology Assessment as of December 1971," Environmental Protection Agency, January 1, 1972

3-3. Final Report - "An Assessment of the Effects of Lead Additives in Gasoline on Emission Control Systems which Might be Used to Meet the 1975-76 Motor Vehicle Emission Standards," Aerospace Corporation Report No. TOR-0172(2787)-2, November 15, 1971

SECTION 4

ASSESSMENT OF AUTOMOBILE MANUFACTURERS' PRODUCTION LEAD TIME

4.1 INTRODUCTORY REMARKS

In preparing an assessment of production lead time requirements for the automobile manufacturers, it is appropriate to review briefly the evolutionary changes in lead time over the last few decades and examine the various factors that impose new risks on the manufacturer of a mass produced product. These discussions have been prepared as an objective means of assessing the current state of conditions in the industry as automobile manufacturers attempt to meet the 1975/76 emission standards.

Lead time is quite fluid in many instances and is influenced by numerous factors such as tolerable risk, rate of expenditures, degree of automation, percent of product line conversion, product complexity, degree of design change, previous experience with product, and rate of production. Historically, lead time schedules were predicated on design changes (whether minor or major) to a limited portion of the manufacturer's product line. In this way the manufacturer's risk in terms of capital commitment or sales volume was limited. In contrast, the design changes instituted by the automobile manufacturers to meet the Federal 1975/76 exhaust emission standards have required significant modifications to the entire product line. This in turn has required the introduction of new manufacturing processes and procedures as well as new fabrication, assembly, and test equipment. In addition to the implementation of a broad series of test fleets, new sources of supply had to be established for the procurement of manufacturing operations and raw materials necessary for the production of catalytic converters - a piece of hardware based on new technology and constituting a major element in the emission control system.

When all car lines are affected, as in this case, the manufacturer's risk is markedly increased. This is due to the fact that emission control systems planned for 1975/76 model year automobiles are based largely on new technology and have not been produced previously. The industry impact is evident when consideration is given to the effect of potential recall or of warranty provisions on every unit. And, in addition, every production unit is affected by the ability of new suppliers and vendors to meet both quality and quantity specifications, not just for one company, but for the entire automotive industry.

Even for sources of proven capability, the means of supplying the entire industry poses a problem. For example, General Motors Corporation may be called upon to supply air pumps (required for the emission control system) for the entire industry unless it can license alternate sources.

Additional risk is inherent in the requirement that the manufacturer commit financial resources to the acquisition of capital equipment and tooling before completion of proof-of-design tests. These research prototype tests are still in process and the results are necessary to provide final proof that the designs being implemented have the ability to meet 1975 emission standards and can function adequately for the 50,000 miles of vehicle operation required by the Clean Air Act. Not only is basic engine operation affected by the introduction of emission control systems, but the overall automobile design must be modified to provide packaging space, handle additional suspended weight, and protect against localized heat loads. Hence, additional road tests are needed to verify all aspects of vehicle operation with a new design.

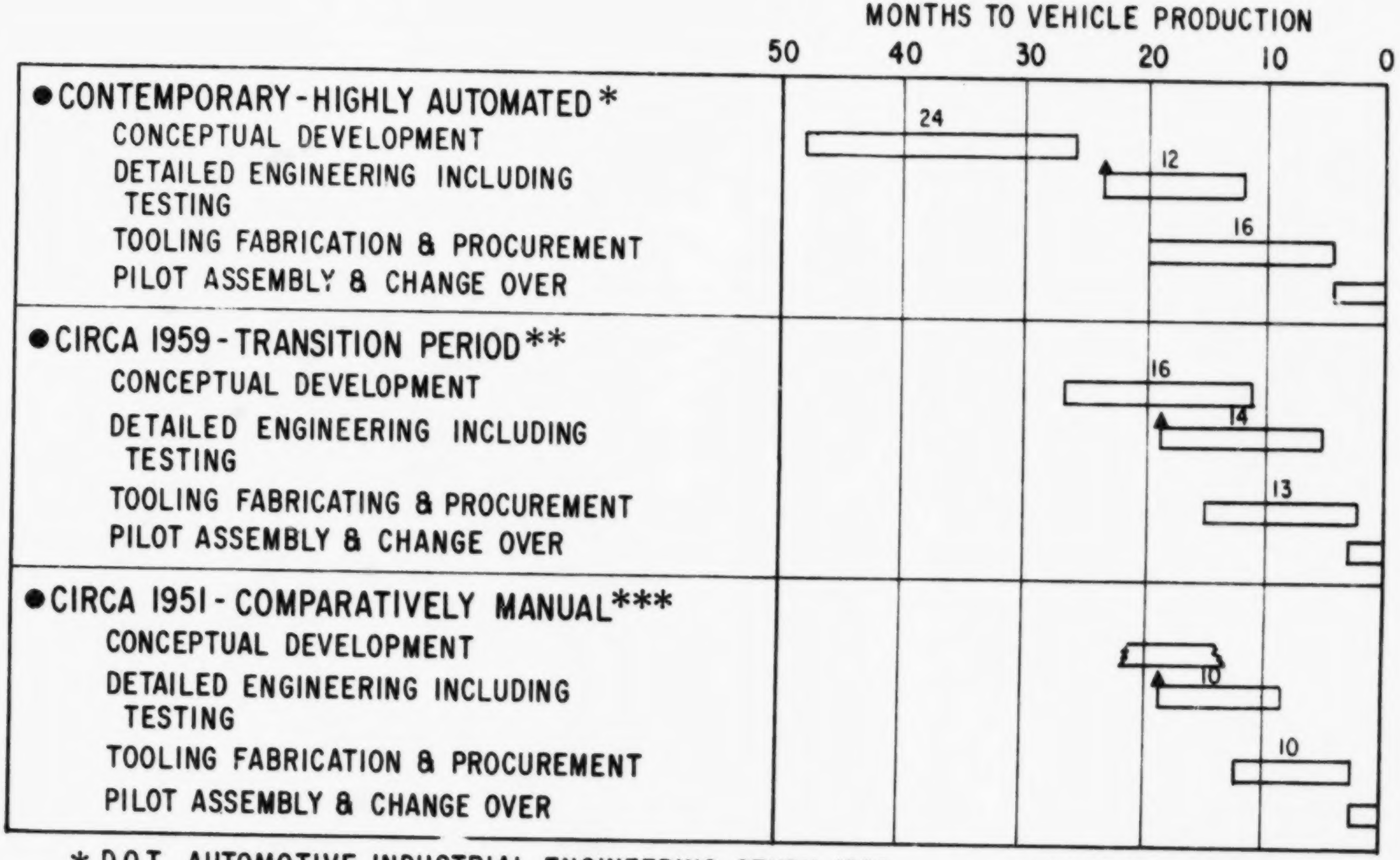
4.2 HISTORICAL REVIEW

Over the last two decades, the production lead time for automobiles has increased. This increase is attributable to a greater use of automated and computerized equipment as exemplified by the General

Motors Vega assembly plant at Lordstown, Ohio. This increased use of sophisticated equipment is regarded as necessary to simultaneously meet higher production volumes, maintain quality control, and offset increased labor costs. Improvements in inventory control (a major cost factor) may also be accomplished.

The increased lead time appears to be brought about through two major steps in the manufacturing development phase. First, there is an increase in equipment procurement lead time due to a greater design effort associated with complex production machinery required to perform a multiplicity of tasks. Second, the equipment checkout time and the period of corrective action is increased as the number of automated operations is increased. Reduction in lead time through the use of overtime labor is difficult since both automobile manufacturers and suppliers may normally work 50- to 58-hour weeks on a one or two shift basis, depending on the type of work and time of year. Furthermore, excessive use of overtime has led to reductions in worker productivity and increases in on-the-job errors. To limit the amount of overtime, in a number of cases, production engineering design was initiated and equipment or tooling orders were placed in advance of management commitment of capital funds. At times these orders can be placed on a tentative contract basis with cancellation clauses having no cost or limited cost provisions.

Considering the large capital investment for automated equipment, the planning efforts prior to financial commitments must be thorough and complete. To provide this background information for management, the conceptual development phase of automobile development has been greatly lengthened. This is shown by the bar chart in Figure 4-1 which depicts the evolutionary changes in lead time over the last 20 years. Although the manufacturing development time has increased somewhat, the greatest change is in the time required for conceptual development.



* D.O.T. AUTOMOTIVE INDUSTRIAL ENGINEERING STUDY, 1968
** CADILLAC, GM ENGR JNL, JULY-SEPT 1959
*** "PRODUCTION OF MOTOR VEHICLES", CUMMINGHAM, McGRAW HILL, 1951

Figure 4-1. Lead Time Trends

Before a given task is transferred from manual to automated operation, a number of factors must be considered, not the least of which is the loss in flexibility for introducing design changes necessary to correct a product design deficiency. Other factors to be carefully considered in an assessment of switching to automated operation are given in Table 4-1.

Lead time has also been markedly affected in the past by the order backlog for different segments of the industry. In the tool and die market, for example, considerable fluctuations in order backlog have occurred -- varying from a large degree of nonutilized capacity in some years (when the automobile manufacturers sought to minimize design changes) to a large backlog in other years (when numerous design changes were called for and labor was in short supply). Problems in the ability of vendors to meet rapid changes in market requirements have led automobile manufacturers to establish many of the vendor capabilities in-house. Hence, automobile manufacturers have tended to become even more integrated in production capabilities over the last decade.

4.3 INFLUENCE OF EMISSION CONTROL SYSTEM

As discussed in Section 3, the exhaust emission control systems planned for 1975/76 model year automobiles are a complex integration of hardware based on new technology. The complexity evolves from a need for these components to function together over a wide operating range (without unduly compromising vehicle performance, driveability, and safety), while meeting the required emission standards. In addition, the designs must be carefully selected to minimize consumer purchase and operating costs. These considerations require an extensive engineering design and test development effort to qualify units individually and then as part of an overall system. Furthermore, each component must be precisely controlled in order to achieve expected performance levels. Current planning of the automobile manufacturers considers that exhaust emission levels on prototype cars must be less than government standards by an estimated margin in order to ensure that emissions from every production car will meet these standards.

Table 4-1. Lead Time Tradeoffs - Automation versus Manual Assembly

CHARACTERISTIC	AUTOMATION	MANUAL ASSEMBLY
TOOLING DESIGN TIME	MAXIMUM	MINIMUM
TOOLING FABRICATION PROCUREMENT TIME	MAXIMUM	MINIMUM
FACILITY DESIGN TIME	NOMINAL	NOMINAL
ASSEMBLY LINE DESIGN TIME	NOMINAL	HIGH
TOTAL LEAD TIME	HIGH	MINIMUM
CAPITAL INVESTMENT	HIGH	LOW
PRODUCTION RATE	HIGH	LOWER
FLEXIBILITY FOR QUICK DESIGN CHANGE	LOW	HIGH
QUALITY MAINTENANCE	HIGH	LOW
COST/UNIT ITEM	LOW	HIGH
POTENTIAL FOR WORK SLIPPAGES	LOWER	HIGH
PRODUCTION RATE FLEXIBILITY	HIGH	LOW

Design problems are not limited to the emission control system. The inclusion of this system requires changes to the entire automobile design because of the need to compensate for the volume displaced, the added weight, the requirement for monitoring system performance, etc. Major elements in the car that could be affected are:

a. Body, including floor pan and firewall
b. Fuel tank
c. Engine
d. Transmission
e. Braking system
f. Suspension system
g. Frame
h. Electrical system
i. Instrumentation and dash board
j. Climate control system

Of course, every effort is made to minimize these interactions and, where a design impact is noted, additional design work may be incorporated to improve component performance, strengthen the structure, or modify styling. In this way, cost increases can be lessened by making multiple design revisions at one time.

Another factor introduced by the emission control system is the increased level of heat generated in the engine compartment and throughout the exhaust system. The heat increase requires evaluation of its effect on passenger comfort and safety and on component performance such as the evaporative emission control system. Therefore, heat shielding is likely to be a requirement.

The same problems are present for the 1976 as for the 1975 system. Substantial research and development efforts are still required to incorporate the reduction catalyst and the greater exhaust gas recirculation (EGR) rates.

While a number of components, such as EGR and electronic ignition, are planned for limited production phase-in prior to the 1975 model year, the catalytic converter is still undergoing development. To date there has been a lack of success with respect to catalyst durability and maintenance of exhaust emission levels below the Federal standards for 50,000 miles. In fact, the catalyst was cited by all automobile manufacturers as the most critical lead time item. Still under design evaluation is canister fabrication and the packaging of the catalyst substrate in the canister, both of which must endure a severe environment of combined thermal and mechanical loads for 50,000 miles.

At the time of the April 1972 EPA suspension request hearings, the information that was provided showed that producers of oxidation catalysts required about 24 to 28 months lead time. This meant that commitments to vendors and suppliers of catalysts had to be made by the automobile manufacturers from April to August 1972 in order to mass produce 1975 model year automobiles by August 1, 1974. (However, the catalyst manufacturers indicated at that time that they could possibly tolerate a slippage of 3 to 6 months with a possible per unit cost increase.)

Ford had already made a commitment to Engelhard Minerals and Chemical Corporation for operation of a catalyst pilot plant and was about to expand the commitment to include the operation of a second full size production plant which would supply a major portion of its production requirements. Since that time, Ford has increased its commitment to Engelhard, General Motors has granted a contract to W. R. Grace and Company for catalyst facility design work only, Chrysler Corporation has contracted with Universal Oil Products Company for facility design work only, and American Motors Corporation has signed a contract (but has not revealed the name of the catalyst company). In addition, General Motors and Chrysler have very recently been in the process of considering commitments to companies controlling the production and distribution of platinum-group metals. In other areas, indications are that orders have been placed for certain long lead time items such as automatic machine transfer lines, particularly where the application of this equipment is to hardware designs that are not expected to change significantly.

Hence, the initial production lead time decision milestone has passed and the automobile firms are proceeding on a risk basis for the manufacture of 1975 cars. However, certain critical phases of the lead time schedule for catalyst manufacturers have not been passed (e.g., facility construction). What this situation implies is that, as long as the prototype tests on cars equipped with catalytic converters are not offering proof of meeting the emission standards over a range of 50,000 miles, the automobile manufacturers are making only staged commitments in order to minimize financial risk in a program that uses what they consider an unproven product.

In the interim, numerous discussions were held between the automobile manufacturers and catalyst manufacturers in regard to design alternatives, production capabilities, and required financial commitments for the future. Preliminary facility design activities were also conducted by the catalyst manufacturers without firm commitments in order to remain in a competitive position.

The next commitments to be made by the automobile firms should occur by December 1972. These would be major commitments calling for construction of catalyst and substrate manufacturing facilities and possibly the ordering of long lead time equipment for these plants. In certain parts of the country concrete foundation pouring must be accomplished before the full winter frost; structural steel and sheet metal walls can then be erected throughout the winter. Facility leasing might also be considered by some in lieu of new facility construction to permit some added schedule compression.

Another decision pending in the period November to December 1972 is the commitment required to steel firms for a significant shift in the production levels of low nickel content stainless steel. (Currently, very little stainless steel is used in the average car.) The degree of use of this material throughout the automobile exhaust system had not been decided upon by the automobile manufacturers at the time of this report. (Additional details are discussed in Section 4.8.)

Evidently a major overlap between engineering development phases and manufacturing development phases has been and is occurring. This state of the industry is far from the normal situation and in fact, is far from normal operation for any mass production industry. While some overlap between engineering development and manufacturing development is necessary to some degree in a competitive industry, the current events may pose greater than acceptable financial risks to the automobile manufacturers. It is expected, then, that the manufacturers will continue to submit requests for suspension of the 1975 emission standards unless some substantial improvement is noted in the performance characteristics of the emission control systems being evaluated in vehicle prototype test programs.

4.4 INFLUENCE OF PROTOTYPE TEST PROGRAM

All of the automobile manufacturers are currently conducting a series of research prototype test programs on their projected 1975 emission control systems. The latest series of prototype tests have been under way for several months. Earlier, laboratory bench tests and dynamometer tests were conducted to develop conceptual designs, and these tests provided data on the most promising systems. The prototype tests now incorporate the best emission control system designs into a test vehicle fleet to evaluate acceptability of each engine/chassis combination from a performance and safety standpoint. These tests are directed mainly at acquiring performance data on catalytic converters operating in an automobile environment with a complete emission control system.

From documentation provided by the automobile firms in support of the April 1972 EPA hearings on requests for suspension of the 1975 emission standards for light-duty vehicles, and from documentation they submitted to EPA in May 1971, it can be inferred that their minimum requirement for initial demonstration of designs in these road tests are:

a. American Motors Corporation. Meet 1975 emission standards and demonstrate emission control system durability for 50,000 miles with five vehicles for each vehicle/engine class (about 60 to 75 vehicles total).

b. Chrysler Corporation. Meet 1975 emission standards and demonstrate durability with four to five cars at 50,000 miles each per model.

c. Ford Motor Company. Meet 1975 emission standards and demonstrate durability with four experimental vehicles at 50,000 miles each.

d. General Motors Corporation. Meet 1975 emission standards with a large fleet of test vehicles at 50,000 miles each.

To date, no domestic manufacturer has been able to demonstrate a successful system design to his satisfaction although some designs have shown marked improvement over earlier versions and have come close to meeting the emission standards at extended mileage on the test vehicles. All indications are that these tests will be continued into 1973 in an effort to further improve operation of the emission control systems.

These research test programs are having a major impact on the introduction of emission control systems into 1975 model year automobiles. The original lead time milestone cited in the April 1972 Suspension Request Hearings for making major catalyst commitments has been passed (April to August, 1972) without a proven design available. Hence, the automobile manufacturers intending to mass produce 1975 model year automobiles by August 1, 1974 have been required to place orders for long lead time equipment and tooling (e.g., automatic machine transfer lines) based on their best judgment as to what will constitute a final design. In addition, subsequent test programs involving the emission control system mounted in cars with representative 1975 designs throughout may be rendered invalid by operating with emission control system hardware that may not be the final design. Furthermore, without a successful design, commitments to manufacturers of substrates and catalysts have been delayed in order to have more data available before making unilateral decisions having high risk. All firms have made some initial commitments in the August to September 1972 period to manufacturers of substrates and/or catalysts. These dates represent a 2 to 5 month slip beyond the commitment dates expressed by the catalyst firms at the hearings in April of this year. From information given in support of these hearings, it would appear that this delay may cause some increase in the unit cost of the catalytic converter components.

4.5 EFFECT OF CERTIFICATION TEST PROGRAM

Certification of 1975 model year automobiles requires that each manufacturer establish baseline emissions at 0 and 4000 miles for each engine family (emission data vehicles) in accordance with the 1975 Federal test procedure. In addition, 50,000-mile tests of a fleet of durability vehicles is required to demonstrate the ability of these vehicles to maintain emissions below the Federal standards. Along with the time required to prepare and submit supporting documentation, the entire program may stretch out over many months.

The durability test alone takes about 5 to 6 months to accumulate 50,000 miles. Unless these tests are initiated as early as possible, there will be little time for recovery from failure of a given engine-chassis combination to pass the test. Accordingly, the first durability test should start no later than September 1973 if two full durability test periods are desired and vehicle production is to start in August 1974.

Where it is necessary to use catalysts not produced with production manufacturing equipment and processes in certification test vehicles, the issue as to whether or not these catalysts are the same "in all material respects" as production units will arise. Due to the basic nature of the substrates and deposited catalytic materials, it may be difficult to verify that catalyst loading, uniformity of loading, and substrate physical characteristics are indeed representative of quantity production units.

4.6 DEGREE OF INDUSTRY SCHEDULE CONSISTENCY

The overall production lead time schedules are summarized for the major domestic automobile manufacturers in Figure 4-2. As can be seen, all company schedules are in reasonable agreement with one another and with the historical model year lead time requirement for major changes of 24 to 28 months. Such consistency is not surprising since all manufacturers are faced with the same critical lead time component, the catalytic converter,

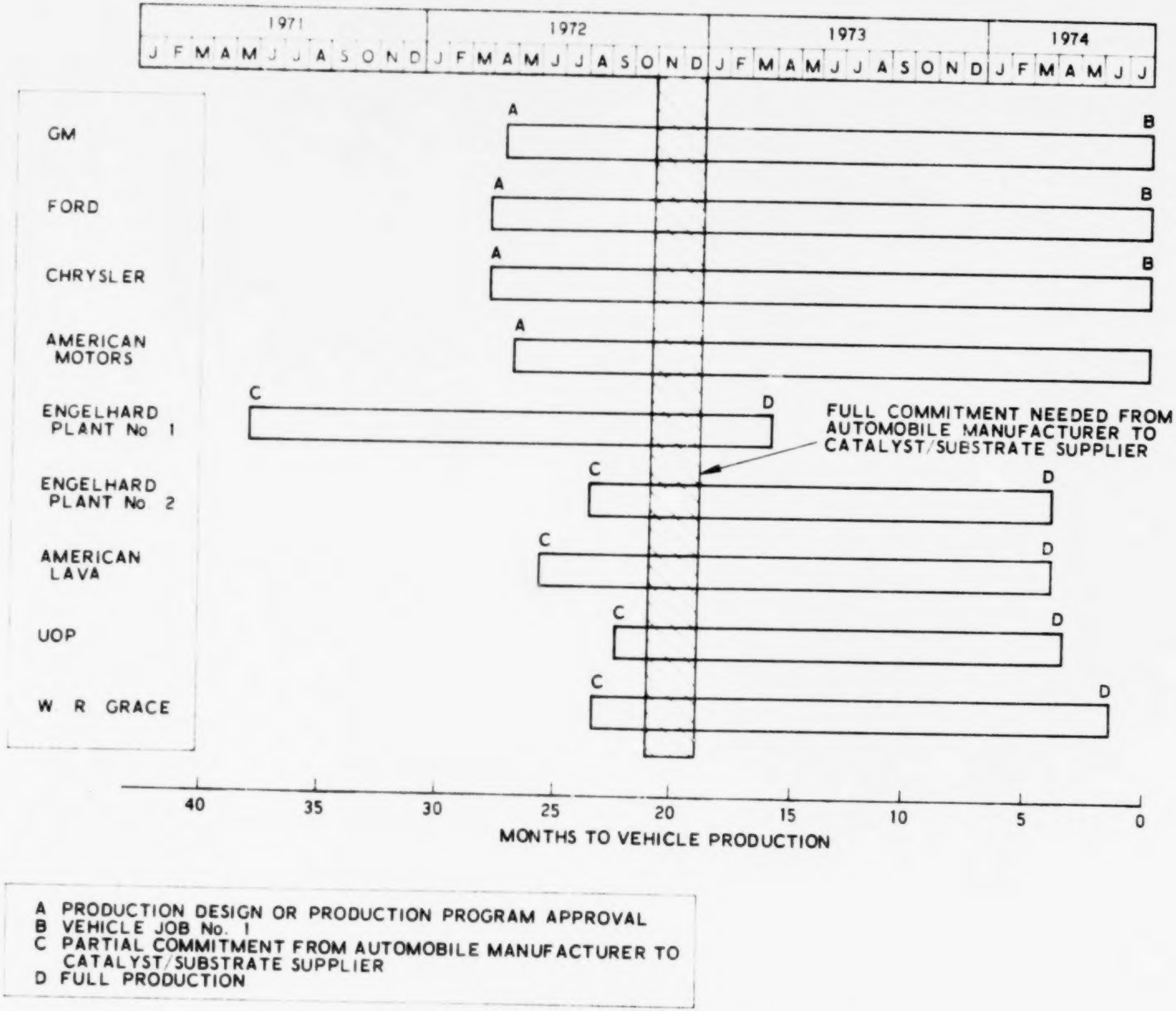


Figure 4-2. Overall Production Lead Time Schedules

and were dealing with the same types of suppliers for catalysts and substrates. Production lead time precedent for major changes (24 to 28 months) was undoubtedly the chief reason that the Production Approval Milestone occurs on the dates shown. Of course, all companies stress that present schedules are optimistic and may not be met because they were required to commit resources to a given design in order to be able to mass produce 1975 model year automobiles by August 1974.

Also shown in the figure are similar current production lead time schedules for representative substrate and catalyst manufacturers. Except for Engelhard, which had the benefit of early commitments by Ford, their schedules are also consistent with one another. Again, this consistency is really related to the time required to design and construct a production facility, and the same factors are influencing each individual schedule.

Finally, the catalyst, substrate, and automobile manufacturers' overall lead time schedules are consistent when compared to each other. This consistency prevails for the reason that the automobile manufacturers' schedules are in turn based on the catalyst manufacturers' schedules as shown.

4.7 POTENTIAL FOR INDUSTRY SCHEDULE COMPRESSION

A reduction in the normal scheduled time for a complete automobile development cycle is possible through three approaches: (a) increase the degree of overlap between various phases in engineering and manufacturing development, (b) extend the use of overtime on a given work shift, or (c) increase the number of work shifts to a maximum of three per day. However, the greater the amount of scheduled phase overlap, the greater the chance for making costly errors through premature decisions. The use of overtime can lead to some shortening of development and production design engineering efforts, but in many cases the equipment and tooling procurement lead time remains essentially unaltered. This is because the major effort on hardware lead time is the industry backlog. If little demand is present, the equipment manufacturer can then concentrate more of his staff for a longer period of time on a given job. Conversely, if there is heavy industry demand, overtime is already being used to a great degree and there is little schedule compression afforded with any added overtime; productivity decreases with excessive use of overtime.

The potential for schedule compression is generally quite small. A 10% to 15% compression is considered to be the maximum feasible with acceptable increase in unit cost. Any additional compression is bought at excessively large cost increases, and at some point no further compression is possible even with costs discounted as a judgment factor. The skilled labor market cannot suddenly be increased to meet a multitude of orders.

Schedule compression is primarily in evidence for only one area: the production of oxidation catalysts. The pacing item is the construction of new facilities. The equipment requirements for these facilities are generally of a standardized design not requiring long lead times. This is where the 10% to 15% schedule compression could be obtained.

With regard to the remaining elements of the emission control system and the vehicle as a whole, the automobile manufacturers are proceeding on what is generally considered as a normal schedule or a partially compressed schedule. This approach is necessary in order to avoid increased costs when using overtime labor and to leave some time available to correct design deficiencies which may appear as the program progresses. A fully compressed schedule leaves no room for correction of mistakes and this approach would have serious impact on the manufacturer through provisions of recall and warranty. Also, any slippage on the part of vendors or suppliers cannot be accommodated. Similarly, labor strikes would alter the entire timetable if the lost work effort cannot be made up.

Lastly, when all car lines of a given manufacturer are affected, uniform, company-wide schedule compression is difficult to accomplish. New production processes are necessary for all lines and phasing difficulties (due to problems in procurement, inventory, and speed in implementing corrective action) may occur between lines having commonality in hardware. The simultaneous introduction of various designs requires increased coordination with vendors. Also, a greater number of new machines stretches out the equipment delivery schedule because the equipment manufacturer generally cannot produce multiple units simultaneously. Likewise, delivery and checkout must be staggered over a period of time.

A maximum possible compressed lead time was not cited by the automobile manufacturers. Presumably this was because such a schedule would be predicated on numerous assumptions inconsistent with reasonable business practice and, perhaps, inconsistent with reality. Among these assumptions would be:

a. Full use of premium time for both automobile manufacturer and vendors.

b. No problems in installation and checkout of equipment or tooling.

c. No labor strikes or building construction delays.

d. No vendor slippage or limit on vendor capacity to supply components, equipment, or tooling.

e. Maximum overlap between production engineering drawing release and procurement of equipment and tooling.

f. Elimination of prototype equipment and tooling; production samples to be made first from production equipment and tooling.

4.8 INDUSTRY CAPACITY TO MEET HIGH PRODUCTION VOLUME

In an industry that produces on the order of 10,000,000 light-duty vehicles per year, a heavy demand is placed on both material and labor resources to meet the daily production rates and the consistent introduction of new vehicles in August of each year. This demand has been met historically with only sporadic interruptions caused by labor strikes. However, with the introduction of emission control systems for every automobile produced, the industry capacity to meet the high production volume is not clearly established and the critical factors must be examined.

Excluding financial considerations, there are four broad areas to consider in assessing the industry capacity to meet demand:

a. Labor force availability
b. Raw material reserves and production capability
c. Processed materials production capability
d. Fabricated products production capability

The succeeding sections will discuss each of these topics in turn.

4.8.1 Labor Force Availability

In regard to the labor force, skilled workers are always in demand, but normal requirements have usually been met. Sudden surges of activity have been accommodated to some degree by the use of overtime labor. However, critical periods have been noted in the tool and die industry, and the lack of success in meeting demand at times has led the automobile firms to assume much of the work load formerly accomplished by independent companies. As far as the introduction of emission control systems is concerned, no labor problems were identified.

4.8.2 Raw Material Reserves and Production Capability

The impact of raw material reserves and production capability is noted in the manufacture of catalytic converters. Alumina (Al_2O_3) for the substrate and wash coat is in plentiful supply, but the supply of noble metals for the catalyst is an issue that is not completely settled at this time.

Currently, the Soviet Union is the largest producer of platinum-group metals, followed by the Republic of South Africa and Canada. Because future platinum-group metal sales by the Soviet Union cannot be accurately predicted, it is likely that South African platinum-group metals will be the primary supply since it appears that the production capacity of the South African mining companies can be sufficiently increased. However, this is contingent on contracts being signed in the near future between the automobile manufacturers and the mining companies. For without such commitments, it is unlikely that the mining companies would proceed with their projected expansion programs because of the large capital investment required.

The platinum-group metal supply-demand balance is determined by the platinum-group metal loading requirement of the automotive catalysts, the number of catalysts required on the various vehicle classes, the catalyst replacement interval, the mining industry capacity, and the degree of platinum-group metal recovery from spent catalysts. A comprehensive analysis of these parameters is urgently needed in order to provide all the data required for a complete and meaningful assessment of the platinum-group metal availability and demand issues.

4.8.3 Processed Materials Production Capability

There are three forms of processed materials that pose a problem for industry capability. First, there is the production capacity needed to form alumina and other compounds into a consolidated form in the shape of pellets or monolith structure for the catalyst substrate. Second, there is the production capability for rolled stainless steel for use in catalytic converter canisters, exhaust systems, and possibly in full-size thermal reactors. Third, there is the capability of foundries to produce sufficient numbers of castings for full-size thermal reactors, if they were to be eventually used. These material resources will be discussed in turn.

4.8.3.1 Production Capability for Catalysts and Catalyst Substrates

The production of catalytic converters (oxidation or reduction) for use in automotive emission control systems requires a high degree of interactive planning and coordination between the substrate, catalyst, and automobile manufacturers. For example, a different company might be involved in each phase of the catalytic converter fabrication and installation for a given automobile manufacturer, or a single company may be engaged in two or more of the catalyst manufacturing phases. On the other hand, an automobile manufacturer might procure basic raw materials and perform all catalyst manufacturing and installation phases in-house.

As of the time of data acquisition (August to October 1972), there was a noted variability in schedule status for the different catalyst and substrate manufacturers. This variability was a result of both the status of financial commitments made by the automobile companies and the amount of funds expended by catalyst and substrate manufacturers themselves in order to be able to compete for potential 1975/76 catalyst requirements. In all cases, there was reasonable confidence on the part of substrate and catalyst manufacturers that if contract negotiations pending with automobile manufacturers resulted in firm production orders in the November to December 1972 period, the currently projected schedules for quantity production of oxidation catalysts could be met. Their judgment was based on long experience in mass producing catalyst-related products for the chemical and petro-chemical industries and in meeting increased demands for products by constructing new facilities or expanding existing facilities. The equipment needs for producing substrates or catalysts are generally quite conventional, are readily available, and, therefore, should pose no problem.

In contrast, the automobile manufacturers have expressed some doubt concerning the ability of the substrate and catalyst manufacturers to meet production demands while maintaining the required quality control. Much of this doubt centers on the fact that catalysts of the automotive type have never been mass produced in the quantities required by the automobile manufacturers.

4.8.3.2 Production Capability for Stainless Steel

Generally, carbon steel has been used for the complete automobile exhaust system. Some automobile manufacturers require the application of aluminum and galvanized coatings to the steel. A chromium-type stainless steel (ASTM TP409) has only been used on mufflers for some customers who have special requirements for the durability of the exhaust system. However, because of the operating characteristics of emission control systems, higher temperatures within the automobile exhaust system may require extensive use of "muffler grade" stainless steel as well as some use of a nickel-bearing chromium-type stainless steel (ASTM TP304), mainly for the catalytic converter canister or for the thermal reactor shell. (It is of interest to note that the price of the raw material for TP409 stainless steel is 25 cents per pound as compared with 8 to 9 cents per pound for carbon steel.)

It is estimated that for a total of about 10 million light-duty vehicles produced annually by the domestic industry, an additional stainless steel production capacity of up to 375,000 tons per year may be required, depending on the extent of use in the exhaust system. The obvious question, therefore, is whether sufficient alloy material will be available to produce stainless steel exhaust systems for 1975/76 model year cars. With respect to chromium, sufficient amounts would be available, mainly from Rhodesia and South Africa. The nickel supply would also be adequate since the new demands by the automotive industry (from 40 to 50 million pounds per year) could be met by the present free world production rate of about 1 billion pounds per year, which represents only 56% of its total capacity. (International Nickel, it might be noted, has a stockpile of 300 million pounds which alone could satisfy the automotive industry's requirements for several years.)

In discussions with the automobile manufacturers, General Motors stated that it will make the canister from a proprietary stainless steel containing no nickel, Chrysler and Ford stated that they would use stainless steel, and American Motors implied it will use the General Motors canister. However, at this time none of the manufacturers have committed themselves to a particular type of stainless steel. It is believed that the reason is they are not fully certain of the operating conditions to which the exhaust system will be exposed.

Because of the uncertainty, none of the automobile manufacturers have committed themselves to any production rates of stainless steel. However, if design studies and tests show that a material like ASTM TP409 is needed, the manufacturers would have to place orders now with the large carbon steel producers, such as U. S. Steel, since the conventional stainless steel producers do not have the approximately 400,000-ton added annual capacity that may be required.

The placement of large orders would require that the carbon steel producers modify some of their normal production operations. The modifications relate mainly to ensuring the purity of the steel by preventing the inclusion of scale. This requires that scale be removed from the stainless steel billets prior to rolling, and that scale be removed from the sheet metal during and after rolling. Necessary equipment consists mainly of grinding equipment for the removal of scale from billets and pickling equipment to remove scale from the sheets. Additionally, some special sheet rolling equipment is required to provide the desired gauge, width, and surface condition. Estimates on lead time range from 18 months to 2 years to modify and procure this new capital equipment.

In summary, raw material availability is not a problem. However, material processing capacity is a problem, but it can be resolved by the timely ordering of additional equipment needed. Critical lead times are mainly related to the capital equipment modifications and new capital equipment required by steel firms to produce whatever type of steel the automobile manufacturers finally decide upon. The fact that the manufacturers have not as yet made a definite decision is a problem that recently has become more significant. Commitments must be made in the November to December 1972 period if 1975 model year requirements for stainless steel are to be met.

4.8.3.3 Production Capability for New Castings

Current first-choice emission control systems incorporate a cast partial thermal reactor for emission reduction during the cold start and for rapid warmup of the catalytic converter. Some of these reactors resemble a slightly oversize standard exhaust manifold while others resemble the full-size thermal reactor in outward appearance but have a volume considerably smaller than the full-size reactor (e.g., 1/3 volume of full-size reactor). The casting capacity to accommodate these types of units is presently accounted for in 1975 model year production schedules.

No domestic automobile manufacturer is presently considering the use of a full-size thermal reactor in its 1975 or 1976 emission control system. However, were such a reactor to be employed, its current development status and casting production lead time requirements make it a nonviable option for the 1975 model year. Ford states that the time is now past the critical point for it to order arc and holding furnaces for foundry operations to manufacture full-size manifold thermal reactors for the 1975 model year. The foundry industry (exclusive of automobile company foundries) indicates that if additional foundry capacity on its part is required, 36 months would be required to achieve full production volume. A definitive assessment of full-size thermal reactor casting capacity and foundry equipment lead time requirements for model years beyond 1975 cannot be made at this time. Such an assessment would require that the automobile companies complete their development programs, delineate their individual requirements, and assess their in-house capacity along with the need for any additional capacity from the outside foundry industry.

4.8.4 Fabricated Products Production Capability

Fabricated products have posed some problems, but it appears that these will be resolved. Under fabricated products can be listed the following:

a. Catalytic converter
b. Traditional components
c. Equipment and tooling

4.8.4.1 Fabrication of Catalytic Converters

If the necessary contractual commitments are culminated by the end of 1972, fabrication of the catalytic converter container and assembly of the unit will be handled adequately by division of work between the automobile manufacturers, the catalyst manufacturers, and independent firms such as Arvin Industries, Walker Manufacturing Company and Canadian Fram, Ltd.

4.8.4.2 Fabrication of Traditional Components

No evidence of problems in the capacity for producing traditional components has appeared, although new fabrication and assembly processes may be required if double-wall exhaust pipes are to be required.

4.8.4.3 Fabrication of Equipment and Tooling

The following discussion pertains to examples of automotive component equipment which is emission control-related, with emphasis on equipment that is unconventional relative to previous automobile production practices.

4.8.4.3.1 Electron Beam Welding Equipment

In order to produce a pebble-type catalytic converter canister, General Motors has decided that electron beam welding of the canister edges is required in the assembly operation. The normal automotive product is resistance welded; resistance welding can be used to spot weld, seam weld, or lap weld light-gauge materials. General Motors claims, however, that resistance welding would be too slow and, therefore, uneconomical and would not seal the container well enough for the contemplated design. Furthermore, this particular canister design requires welding of four thicknesses of material which does not lend itself to resistance welding.

Electron beam welders were initially designed to weld only equipment that was enclosed in a high vacuum environment. The high vacuum unit requires expensive pumping equipment and is a slow production unit because of the delays incurred for the required chamber evacuation. This environmental requirement was considered undesirable by General Motors and canister welding in a nonvacuum environment is being planned. The broader weld given by the nonvacuum unit should aid in providing a reliable seal for the canister.

A prototype, manually operated machine was delivered to General Motors by the Hamilton Standard Division of United Aircraft Corporation in September 1972 to develop techniques for producing canisters. This machine did not incorporate automatic handling equipment and operated at a slow production rate. The six production machines contemplated will incorporate automatic transfer and handling equipment and will produce parts at much higher rates than the prototype machine. Hamilton Standard has the capacity to meet General Motors requirements and can meet schedules if given an order early in November 1972.

4.8.4.3.2 Valve Seat Hardening Equipment

The low lead content of the gasoline required for automobiles incorporating catalytic converter systems has an adverse effect on the life of conventional valve seats. For this reason, the automobile companies are induction hardening the valve seats to compensate for the protective quality of the lead.

This modification of the cylinder head affects the machining and transfer equipment which now has to incorporate a valve seat induction-hardening station. This feature has been incorporated on all known cylinder head production equipment. The device is made by the Tocco Division of Park-Ohio Industries, Inc., which is the only company known to supply it. No evidence of criticality of availability was found; therefore, it can be assumed that this equipment presents no lead time problems.

4.8.4.3.3 Cylinder Head Machining and Transfer Equipment

American Motors has had problems with exhaust valve life due to excessive heat. High temperatures have caused erosion with resultant unacceptable leakages. For this reason, it is redesigning the cylinder heads to improve cooling capacity by replacing the present one-piece core casting with a two-piece core casting. This change will require new cylinder head machining and transfer equipment to fabricate the new heads. At this time, American Motors efforts are in the development stage; it has made about 50 prototype cylinder heads using soft tooling. As explained in Section 8.1, the procurement of cylinder head machining and transfer equipment has a lead time of approximately 20 months prior to vehicle production. This implies that American Motors must place an order for production equipment before the end of 1972. No problem in supplying this equipment is envisioned.

4.9 TECHNOLOGICAL IMPLICATIONS OF ALTERNATIVE PLANS

Were Federal regulations to be relaxed, a number of alternative plans could be considered by the automobile manufacturers in lieu of meeting the Federal emission standards with 1975 model year automobiles in full production by August 1, 1974. Consideration of these plans depends on judgments leading to decisions that would have to be made by the Federal government.

If the Federal government were to grant a 1-year extension to automobile manufacturers for meeting the 1975 emission standards, the risk of introducing unproven designs for the emission control system would be reduced. Prototype testing could be continued for a longer period to allow for development of higher performance and more reliable designs, and the overlap between these tests and the manufacturing design phases could be lessened to reduce the risk of making design decisions based on preliminary information. The impact on the rest of the industry could be a deferment in purchase of equipment, tooling, components and raw materials. Most affected would be the catalyst industry which is just starting to implement facilities for mass production of substrates, catalysts, and container fabrication and packaging. Some decisions regarding the purchase of raw materials (e.g., platinum-group metals) may not be deferrable once a commitment has been made; the procurer of these materials may then have to carry a costly inventory until production finally gets under way.

Furthermore, were a one-year suspension to be granted, the Federal government must issue a set of interim standards for exhaust emissions. If these standards could be met by the catalytic converter systems presently developed or under development (either by virtue of raising the emission standards levels or by revising the replacement intervals for converters, etc.), then the impact on the industry noted above could be averted.

Alternatively, the use of full-size thermal reactors is not considered a viable option for 1975 model year automobiles, even if interim emission standards could be met by them. This is because the automobile companies have not been developing the thermal reactor as a first choice system and have not therefore proceeded to order the necessary long lead time production equipment, as they have been doing for catalytic converter systems.

Less effective partial thermal reactors, smaller in volume and less complex than full-size thermal reactors, are currently programmed for use in 1975 emission control systems. These could be used without catalytic converters but the resulting emission reduction capability is at present not well defined and could vary among the different automobile manufacturers, according to individual design details. Some partial thermal reactors resemble a slightly oversize standard exhaust manifold while others resemble the full-size reactor in outward appearance, while having a volume approximately 2/3 less. At present such partial reactors are designed primarily to oxidize HC and CO during the cold start period and to aid in warming up the catalytic converter.

If the interim standards would simply permit the continued production and sale of 1974 model year type automobiles for another production year, the manufacturers would have to be apprised of this situation prior to January 1, 1974. There still would be a lead time consideration with the extended production of the 1974 model year, since orders must be placed in advance of August 1974 production in order to continue supplies of raw materials and components and to replace worn out tooling.

Without a 1-year suspension of the emission standards, the automobile manufacturers might consider continuing production of 1974 model year cars throughout calendar year 1974, subject to approval by the Federal government. This would provide more development and certification test time for the 1975 emission control system. From a competitive marketing standpoint, of course, such an action might create a reduction in sales for those manufacturers requiring the longest delay in the eventual introduction of 1975 model year cars.

4.10 PROGNOSIS FOR 1975/76 LEAD TIME REQUIREMENTS

At the present time, all major domestic automobile manufacturers are proceeding on a high risk basis with the necessary steps to ensure that 1975 model year cars will be in full mass production by August 1974. Orders have been placed for long lead time equipment for all well-defined car systems; component orders will follow shortly.

Design efforts are still in progress on components and systems not fully defined. These relate to the catalytic converter and its impact on other areas of the vehicle such as the floor pan and dashboard. Decisions have been delayed in order to take full advantage of data from the research prototype test car programs. These tests are expected to continue into 1973 since the automobile manufacturers maintain they have not been able to find a case of an emission control system that meets government regulations. With regard to catalytic converters, some automobile manufacturers must still decide on pellet versus monolithic substrates and promoted base metal versus platinum-group metal catalysts.

The delays in final design decisions have also led to delays in commitments to critical suppliers. Some limited commitments have been made to catalyst firms. These commitments cover only engineering and design for new or expanded facilities. Except for the Ford contract with Engelhard, no full commitments have been made that would entail actual construction and ordering of equipment.

Current schedules have been compressed slightly from those previously cited by the automobile manufacturers. Additional compression is unlikely except for a few isolated cases and in general, would represent cost increases to the end product. In general, all the automobile manufacturers show good schedule consistency when compared with each other and when compared with their suppliers, particularly those companies supplying catalysts and catalyst substrates.

While staged commitments have proven successful in providing for initial work efforts, the time is at hand for making full commitments to all critical suppliers. These include catalyst and catalyst substrate manufacturers, stainless steel manufacturers, and producer/refiners of platinum-group metals. Sometime in the period of November to December 1972 the automobile manufacturers will have to conclude such arrangements in order to meet the lead time requirements for 1975 model year cars that incorporate the latest emission control system designs which offer the best chance for meeting government regulations.

SECTION 5

LEAD TIME SCHEDULES FOR AUTOMOBILE MANUFACTURERS

This section of the report discusses manufacturing development schedules and lead time requirements pertaining to 1975 model year emission control system production for the four major manufacturers of domestic passenger automobiles. These manufacturers are the General Motors Corporation, Ford Motor Company, Chrysler Corporation and American Motors Corporation. It will be observed that the emphasis in the material presented for the individual manufacturers differs somewhat from one to another. This variation in emphasis directly reflects the nature of the information released by each manufacturer for publication in the open literature.

The critical, or pacing, element of lead time among all the automobile manufacturers concerns the catalytic converter emission control device. The controlling schedule factor is the development of vendor and/or in-house facilities for mass producing catalytic converter components. With regard to monolithic type converter systems, the critical aspect of converter production appears to be the development of a new mass production technology covering the design, fabrication, and checkout of equipment required for the substrate coating operations, particularly the application of the platinum-group metal catalyst. For the pellet-type systems, the critical lead time aspect relates to the development of specialized production line equipment required to fabricate and assemble elements of the converter canister.

For all manufacturers, experimental prototype testing and development of 1975 emission control system design options is continuing as of this date. With reference to production scheduling, the timing of this testing and development activity is regarded as highly extraordinary in that it penetrates well into the production development phase of the manufacturing schedule. According to the manufacturers, test results to date provide no assurance of culminating in a satisfactory design. Normally, new functional car systems that are imperfectly developed at this stage of car development are deferred to subsequent model year production programs.

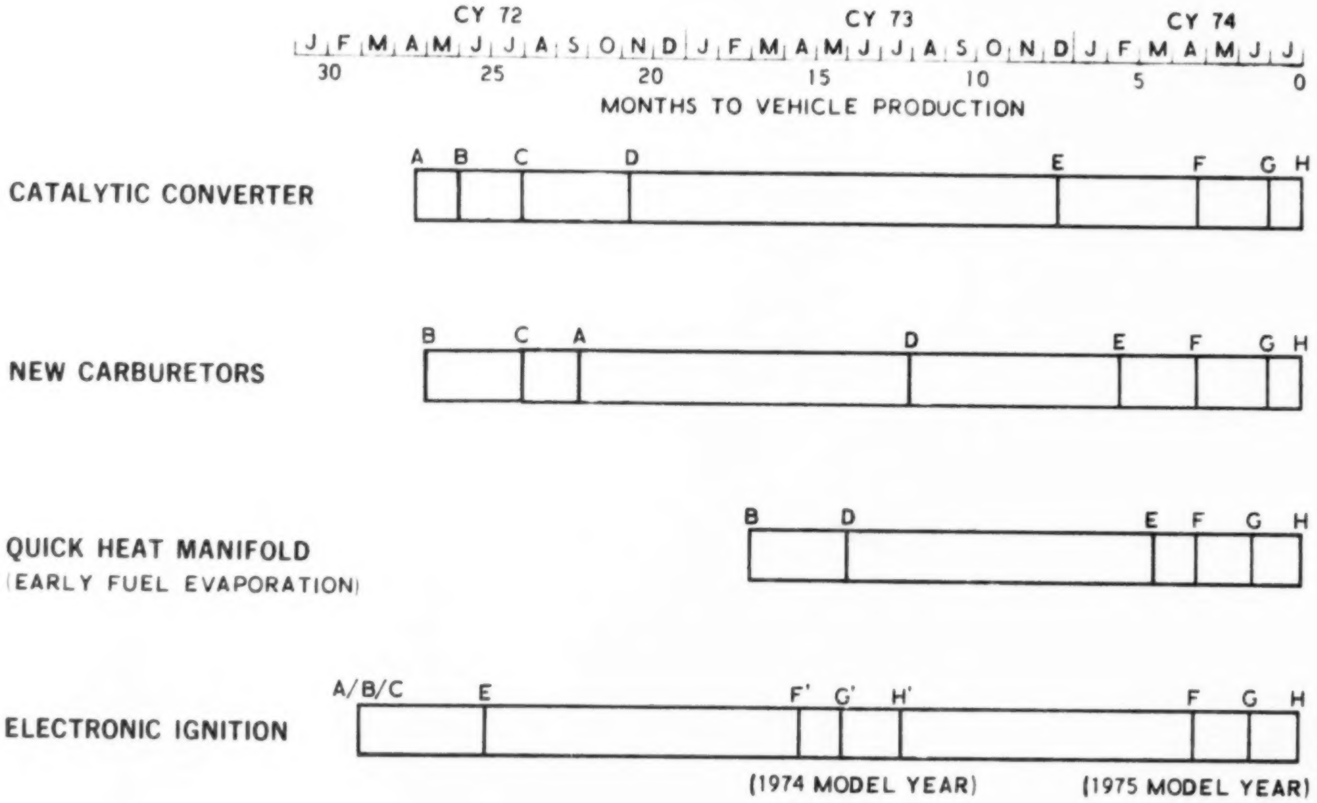
Notwithstanding this current lack of suitable emission hardware to meet 1975 goals, the automobile manufacturers appear to be proceeding on production development schedules that are basically the same as those submitted in the requests for suspension of the 1975 standards and that are intended to provide full production of 1975 model year automobiles by August 1974.

5.1 GENERAL MOTORS

5.1.1 Overall Schedule

5.1.1.1 Production Schedules

The 1975 emission control system master timing schedule for General Motors is presented in Figure 5-1. This schedule shows only the deadlines for those component systems still under development and which could impact the 1975 production lead time. These are the catalytic converter, improved carburetion, and early fuel evaporation (EFE) systems. The 1975 unitized ignition system schedule also is shown. This timing schedule is structured to have car assembly start approximately the first week of August 1974 with component full production commencing 1 month earlier for the carburetor and catalytic converter, and 2 months earlier for the unitized ignition and EFE systems. It is to be noted that the first milestone with respect to production lead time, the tooling and facilities



A - PRODUCTION DESIGN PRELIMINARY APPROVAL
B - TOOLING & FACILITIES PROGRAM APPROVAL
C - START PRODUCTION TOOLING
D - START PRODUCTION PRETEST BUILD FROM PARTIAL TOOLING
E - START PRODUCTION SAMPLE BUILD
F - START VEHICLE PILOT PART PROGRAM
G - FULL COMPONENT PRODUCTION
H - START VEHICLE PRODUCTION

Figure 5-1. General Motors Master Timing Schedule for 1975 Emission Components

appropriation approval date for the carburetors and catalytic converter, occurred in May and June of 1972. The corresponding date for the unitized ignition system is March 1, 1972 for 1974 model production. Since this ignition system will be installed in 1974 models, this item should not be a critical impact factor with regard to the 1975 model year production schedule. The EFE system appropriation approval date is scheduled for March 1, 1973.

Not listed are some emission control devices already in general use, such as a modified spark timing system, the pollution control valve (PCV), the air pre-heater, and the evaporative emission control system. Other devices such as the air injection pump and exhaust gas recirculation (EGR) will be used on practically all 1973 models, and General Motors plans to increase its production in increments with improvements incorporated annually until full production coverage in 1975 is achieved.

General Motors considers this timetable to be more theoretical than realistic, since it is based on the assumption that all the devices needed to achieve 1975 emission levels can be developed in time, and that the manufacturing and assembly equipment necessary can be designed, built, installed, and brought up to production capacity within this period. Nevertheless, this schedule, which was presented at the April 1972 Suspension Request Hearings was still considered by General Motors to be essentially valid at the time of the present investigation.

It should be noted that there are other changes which are required to accommodate the new emission control devices. Although not included in the schedule in Figure 5-1,these changes are to be accomplished within the period shown. Affected items include - linkage mechanisms, vacuum hose connections, and sensor and fuel line routings for new carburetors; new intake and exhaust manifold systems required with the new carburetors; new configurations of exhaust piping; and vehicle changes such as new frames and new body configurations that must be designed to accommodate the new emission control devices.

With respect to the catalytic converter system, General Motors has adopted a basic change in direction since the Suspension Request Hearings. At that time, the basic system being pursued was the base metal pellet, under-floor catalytic converter system. General Motors is now planning to incorporate a mix of both platinum-group metal and base metal pellets in its under-floor catalytic converter. Also, it is actively working on the development of a new system called the triple-mode (or T-MECS) emission control system. This system incorporates a catalyst in a container that is cast into the exhaust manifold. Both concepts are being pursued and the final selection is still some months in the future. Prototype testing of both systems is in progress; some encouraging results have been obtained at low mileage conditions, but no high mileage data have been obtained to assure either durability or the capability to meet 1975 emission standards under these conditions.

Production equipment development activity schedules for the two new catalytic converter systems described above are shown in Figures 5-2 and 5-3. Both schedules indicate that manufacturing equipment development is to be initiated in August 1972. The end date for production startup is the same for both. The schedule for the under-floor converter is essentially the same as the "compressed" process development and manufacturing timetable presented in the General Motors suspension request document. It is noted that the start date (for the production equipment development phase) has been slipped by 1 month and that the new schedule exhibits greater overlap of activities in the early stages of the program.

The General Motors carburetor program is based on producing a family of both improved and new carburetors that will provide the precision fuel metering required to help meet the 1975 emission standards. The schedule shown in Figure 5-4 delineates the time phasing and duration of the various activities related to production development for the new carburetors.

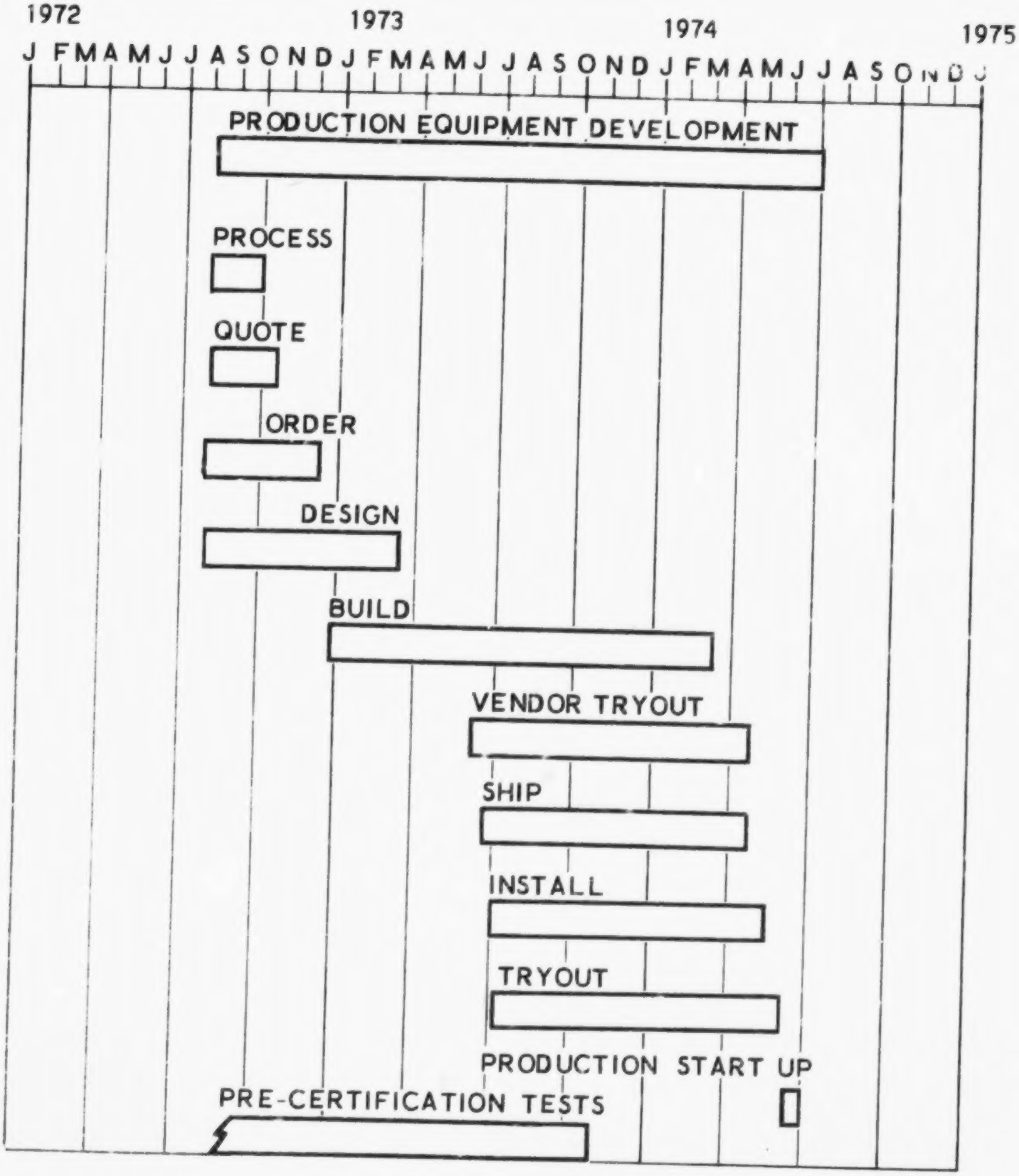


Figure 5-2. General Motors Production Equipment Development Schedule for 1975 Model Year Under-Floor Oxidizing Catalytic Converter (Compressed Schedule)

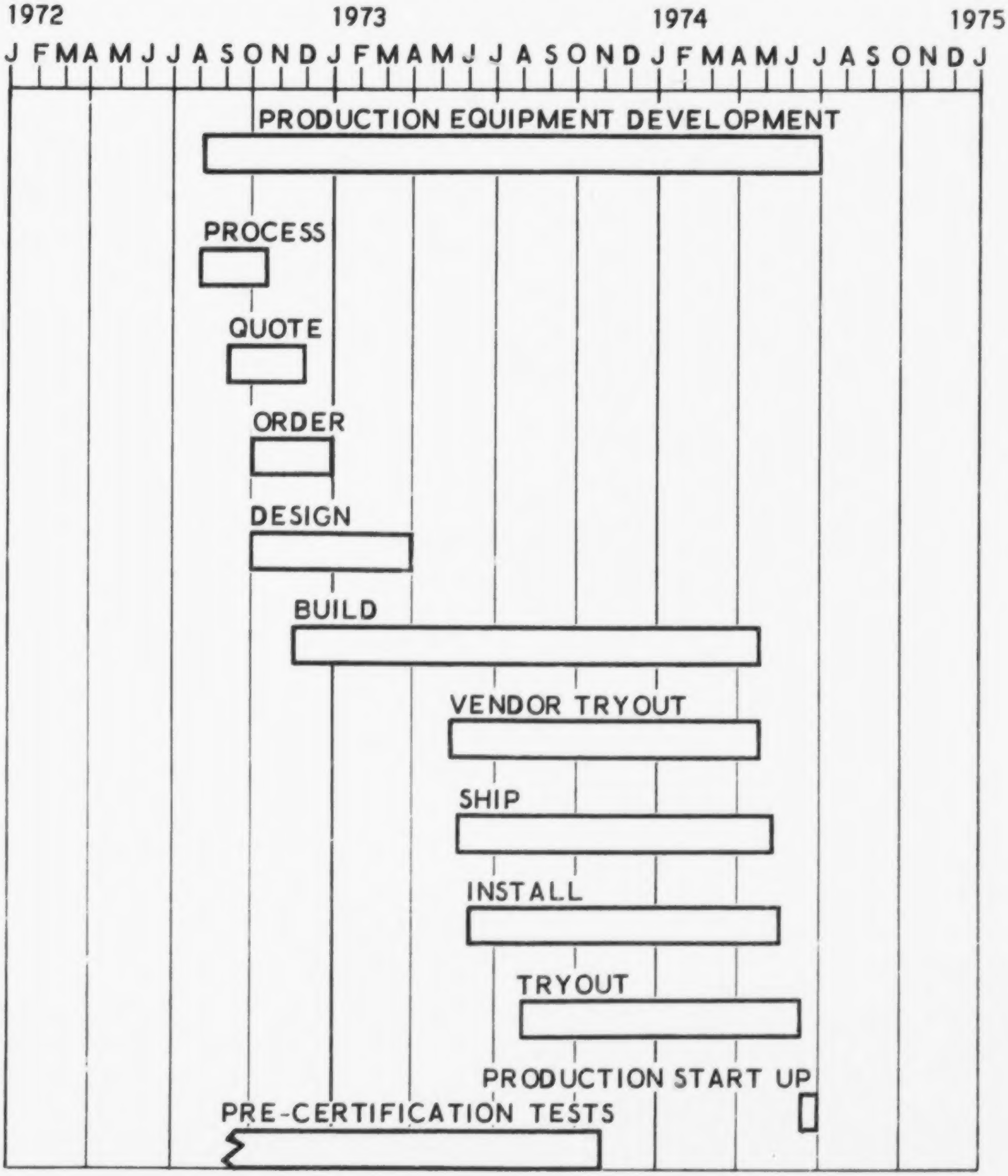


Figure 5-3. General Motors Production Equipment Development Schedule for Manifold-Mounted Oxidizing Catalytic Converter (Compressed Schedule)

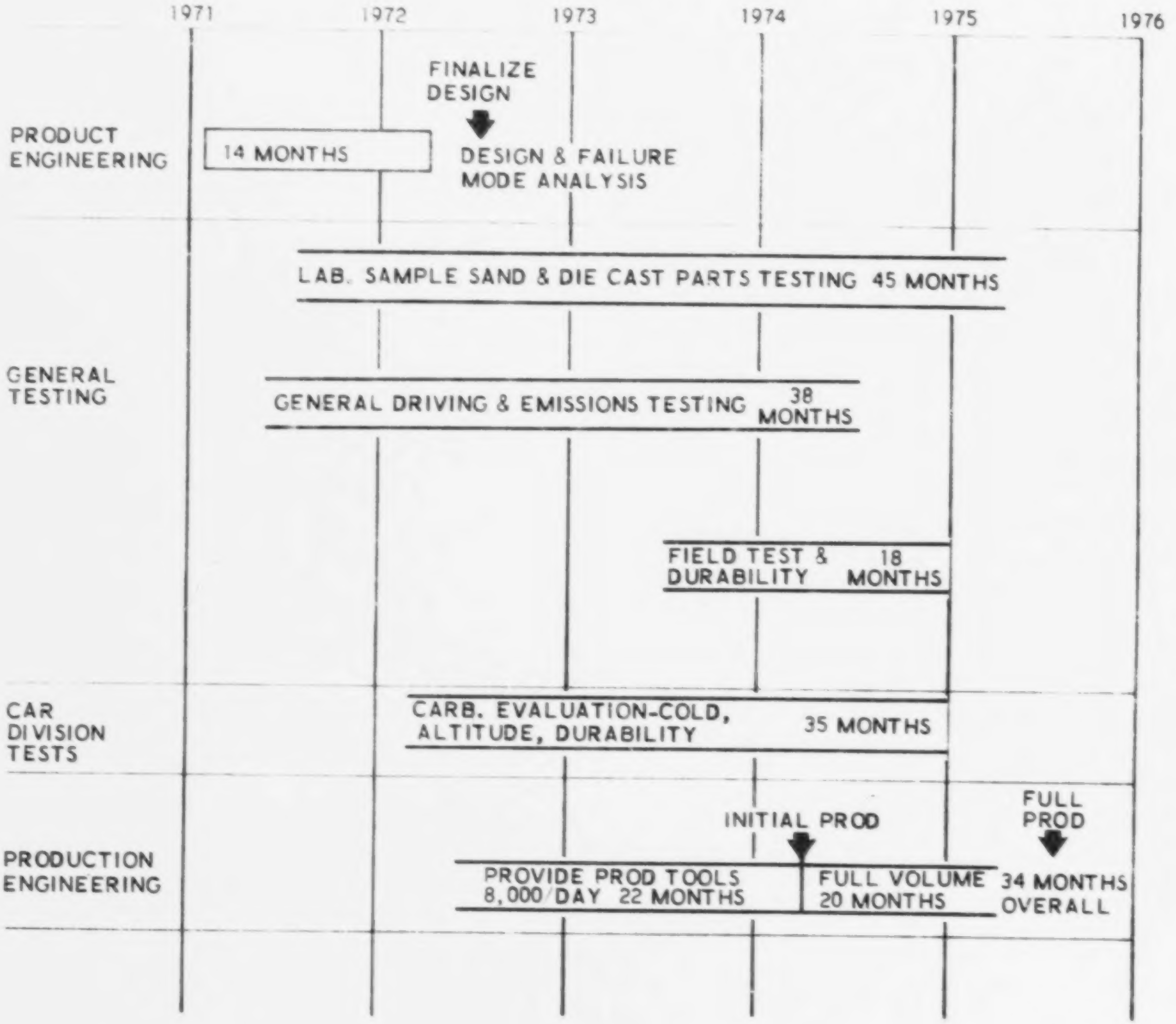


Figure 5-4. General Motors New Carburetor Lead Time

This schedule shows a two-phase overlapping program covering the 1975/76 model years. The objective of General Motors is to be ready to produce 8000 units per day of the new two-barrel design at the start of 1975 production. The balance of 1975 production will be revised versions of the existing carburetor. This plan, General Motors emphasizes, is dependent upon the success of the emission system now being developed to meet the 1975 federal emission standards. Release of long lead time facilities to cover the production of the full volume of 30,000 new carburetors per day for 1976 will be started in mid-1973. This two-phase program takes 34 months to complete. General Motors estimates that a 26-month lead time would be required if the full volume of nearly 30,000 new carburetors were to be introduced at the start of the 1975 model year. That time is no longer available.

5.1.1.2 Major Impact Factors

Although to date General Motors has not demonstrated that its emission control systems will meet the 1975 federal emission standards, it is compelled to make commitments for equipment and components to meet the 1975 production target date.

The component having a major impact on production lead time is the catalytic converter. With regard to the under-floor catalytic converter, General Motors recent decision to incorporate platinum-group metal in its pellet-type system has further intensified the testing activity and delayed the attainment of certain design milestones for this system. At the present time, this under-floor system is still regarded as the prime system for 1975 production. Many engineering commitments with respect to the container have been made; for example, the AC Spark Plug Division has developed a set of hard dies, and engineering has been accomplished for the automatic assembly equipment. At the time of this investigation, the catalyst supplier had not been selected, although General Motors indicated that a decision would be made very soon.

Production equipment development for the catalyst container is considered to be a major schedule impact factor. In mid January 1972, General Motors arrived at what it believes to be a satisfactory container design (providing manufacturing difficulties did not occur). At the time of the Suspension Request Hearings, General Motors indicated that the longest lead time item of equipment for container production was the electron beam (E-B) welders. General Motors feels that electron beam welding is the only practical way to edge-weld the converter canister components to eliminate leakage. The E-B welders used would be the largest machines available.

Figure 5-5 shows the lead times associated with various production line equipment needed to produce the under-floor catalyst container. The composite lead time of 104 weeks is dictated by the 104 weeks necessary to obtain the six E-B welding machines required. The lead time necessary to acquire the first welder is 74 weeks. Other line equipment requiring long lead times (but less than the six welders) are the multi-spot-welder station, rotary MIG welder, catalyst fill machine, leak test machine, and the crimp machine. These items require approximately 80 weeks lead time.

With respect to the manifold mounted, or T-MECS, system, General Motors is investigating an extruded monolithic converter. At the present time, General Motors is proceeding with plans to build its own monolithic converters. At the same time, it is still considering outside vendors. Engineering has been completed on defining the assembly operations for the monolithic converter. This includes making the ceramic substrate paste, extruding this material, cutting the resulting cylinder, and applying the platinum-group metal. The planned assembly line will have an automatic reactants test for every converter to verify its conversion capability. Regarding the status of the equipment for manufacturing the monolithic catalysts, General Motors presently has a pilot-type, manually operated extruding machine at the AC Spark Plug Division.

	PROCESS	QUOTE	ORDER	DESIGN	BUILD	VENDOR TRYOUT	SHIP	INSTALL	AC TRYOUT	FULL PROD	TOTAL
COMPOSITE TIMES, WEEKS	5	6	6	16	34	10	3	10	3	11	104
LINE EQUIPMENT											
SPEC MULTI-SPOT WELDER (4)	6	6	6	6	34	3	2	2	1	2	68
DC PROJECTION WELDER	7	6	7	6	26	2	2	1	1	1	59
SPEC MULTI-SPOT WELDER (4)	6	6	6	6	34	3	2	2	1	2	68
SPEC MULTI-SPOT WELDER (2) STA	4	6	5	10	42	4	2	2	2	3	80
SPEC ROTARY MIG WELDER	3	6	4	5	54	2	2	1	1	2	81
SPEC ROTARY MIG WELDER	3	6	4	6	54	2	2	1	1	2	81
SPEC 2 HEAD MIG WELDER-CAM OP	8	6	8	6	24	2	2	2	2	3	63
SPEC 2 HEAD MIG WELDER-CAM OP	8	6	8	6	24	2	2	2	2	3	63
E B WELDER 1ST MACHINE	2	7	5	6	24	6	5	3	3	3	74
TOTAL FOR 6 MACHINES	2	7	5	16	54	6	5	3	3	3	104
SPEC (2) HEAD ROTARY SIZING MACH	7	6	7	8	24	2	2	1	1	2	60
SPEC (2) HEAD MIG SPOT WELDER	7	6	7	6	28	2	2	1	1	2	62
SPEC ROTARY HEAD MIG WLDR-INLT	8	6	8	4	24	2	2	1	1	2	58
SPEC (2) HEAD MIG SPOT WELDER	7	6	7	6	28	2	2	1	1	2	62
SPEC ROTARY HD MIG WLDR-OUTLT	8	6	8	4	24	2	2	1	1	2	58
SPEC CATALYST FILL MACHINE	5	6	5	12	38	3	2	2	2	3	78
DRIVE FILL PLUG TO TORQUE LIMITS	8	6	8	5	19	1	1	1	1	1	51
LEAK TEST	4	6	5	10	42	4	2	2	2	3	81
MARKING MACHINE	8	6	8	6	22	1	1	1	1	1	55
SPEC CRIMP MACHINE	4	6	5	10	42	4	2	2	3	3	81
MIG SPOT WELDER - COVER 6 PLACES	6	6	6	8	36	2	2	1	1	2	70
SPEC MIG WLDR(2) ROTNG HDS-BRKT	6	6	6	8	36	3	2	2	3	3	75
WATER LEAK TEST STAND - SALVAGE	8	6	8	4	20	1	1	1	1	1	51
SPEC CRIMP MACHINE - (FILL HOLE)	7	6	7	8	24	3	2	1	2	2	62

Figure 5-5. General Motors Composite Times to Secure Equipment (Under-Floor Catalytic Converter)

Another item considered to be a schedule impact factor is the improved carburetor. The Rochester Products Division of General Motors is responsible for the fuel system and thus for the carburetor. This division is presently working on a new design of both two-barrel and four-barrel versions. General Motors plans to have revised versions of existing carburetors as well as new-design carburetors for 1975. It plans initially to produce 8000 carburetors per day of the new design and to gradually phase this carburetor into full production for 1976. Progress to date indicates that the long lead time items are now being ordered and that the carburetor calibration systems are to be ordered in November 1972. Additions to the plant at Rochester Products are being made, and the plant is scheduled to be occupied in November 1972.

The EFE system (previously called a quick-heat intake manifold) is a system which accelerates the evaporation of fuel during engine warmup to reduce exhaust emissions during the first 120 seconds of the Federal test cycle. This will involve the redesign of engine components to accommodate the concept. The development of this concept and its attendant engine component modifications is in process. General Motors emphasized that only limited running of the complete system has been accomplished, and that much more data must be accumulated on various engine and car combinations in order to arrive at the system to be incorporated into production. Tooling commitments do not appear to be critical at this time,based on its early successful development.

5.1.1.3 Critical Lead Time Items

The principal critical lead time element in the General Motors production program concerns the manufacture of the catalytic converter system. For the under-floor catalytic converter, the longest lead time item is the E-B welder. General Motors called attention to this welder as a possible source of schedule delay on the basis of lack of experience with this equipment in this particular application. Good corrosion-resistant steel for the catalyst container has been developed but General Motors has had no production experience with the material with respect to its capability to form into needed shapes, or its weldability.

The basic structure of the catalyst container consists of upper and lower shell halves that are stamped out of sheet metal. The container for the pellets consists of two perforated plates inserted between the two halves. Attached to the container are sleeves used to fill and remove pellets plus inlet, exit, and bypass sleeves. The manufacturing process starts with assembly and welding of the lower shell and fill bushing. This is followed by assembly of the upper shell. After this operation, the pellet container plates are spot welded to their respective container halves and the complete container is then ready for welding. The outer flange will use E-B welding by the somewhat unconventional ambient air welding method. The E-B welding operation is performed in a lead-lined enclosure to safeguard workers from x-rays generated by the ultra-high voltage E-B gun. Following welding, the pellet-type catalysts are inserted into the container by a catalyst fill machine.

General Motors has actually started design and has placed orders for some of the long lead time items of equipment for canister production. The Hamilton Standard Division of United Aircraft Corporation manufactures the E-B welding equipment and has recently delivered the first prototype E-B welder to AC Spark Plug for equipment evaluation and development and training of personnel.

Specific critical items were not delineated by General Motors for the T-MECS system; however, since this system has had less development time than the underfloor catalyst system, it should be identified as a critical lead time item. A start has been made in placing purchase orders for long lead time production items for this system. Monolithic catalysts have been manufactured at AC Spark Plug on a pilot plant basis, but not with automatic assembly equipment.

The vendors' lead times for the carburetor, electronic ignition, and EFE systems are not critical. For those systems, General Motors lead time for capital equipment procurement and the time required for adequate field testing exceed any of the vendor lead time requirements. With respect to the unitized ignition system, General Motors indicated that its own production equipment development was approximately on schedule. As mentioned before, the EFE system is not a critical item. General Motors is fully committed to the carburetor programs, and plant and capital equipment commitments have been made. The carburetor does not depend on which of the two catalytic converter systems is to be selected.

5.1.1.4 Prototype Test Programs

According to General Motors, a total of 380 catalytic converter systems had been built and tested during the 2 years preceding the April 1972 EPA Suspension Request Hearings. Emission test results from 50 low mileage experimental systems were included in the General Motors submission. These encompass tests on a variety of catalytic converter types and makes, including platinum-group metal monolithic and base and/or platinum group metal pellet designs. No success has been experienced to date with respect to demonstrating 50,000 miles durability.

General Motors test program for EPA certification involves a minimum of 13 durability test cars. This phase of its certification test program is scheduled to begin in November 1973. In addition to the certification test fleet, General Motors will pretest 13 similar vehicles to verify emissions and durability. A concurrent test program will check out the cars from the standpoint of driveability, fuel consumption, safety, mechanical durability, etc., under customer driving and variable weather conditions. This will be done on its own proving ground. Because of the large number of models, engines, and transmission options provided, the test program will be designed on a statistical basis to verify satisfactory performance and operation over the broad spectrum of hardware combinations. The number of cars to be tested in this program has not yet been determined.

In addition to the above, General Motors is operating a baseline test fleet to determine the durability of the catalytic converter canister. Additional insight into its prototype test programs can be gleaned from the information supplied by General Motors with respect to the new carburetor program. In this regard, road tests started in May of 1971 on features and ideas for perfecting general vehicle driveability in concert with low emissions. This effort encompasses a 38-month detailed program which includes a time allowance for cold, hot, and altitude testing. General Motors plans to make a final evaluation at altitudes in the Colorado area. This effort was carried out under the complete control of Rochester Products, its design-responsible division. Further field tests for long range durability are planned by Rochester Products for the summer of 1973.

In addition to the tests described above, the respective car divisions will conduct tests which are required to perfect or demonstrate the individual carburetor models projected for use in 1975 cars. A total of 75 models are anticipated, each of which must be tailored for maximum performance and minimum emissions. A 35-month carburetor evaluation program will be conducted by the car divisions to evaluate the different carburetor models to be used. As an example of the extent of this program, General Motors cited that in the current two-barrel carburetor test program a total of 95 samples are now undergoing testing: 47 at the car divisions and 48 at Rochester Products. Of the Rochester Products units, 5 are on the engines of vehicles, 39 are undergoing laboratory testing, 2 are at the Milford proving grounds, and 2 are at the Phoenix and/or Denver proving grounds. For the new four-barrel carburetor, a total of 85 samples are in test: 25 at the car divisions and 60 at Rochester Products. Out of these 60, 3 are on engines and vehicles, 50 are undergoing laboratory tests, 5 are at Milford, and 2 are at Phoenix or Denver.

Prototype testing and final hardware definition must be completed by November 1973 in preparation for the start of durability testing for EPA certification.

5.1.1.5 Schedule Compression

General Motors refers to the production development schedules for its catalytic converter systems (Figures 5-2 and 5-3) as "compressed" schedules. The basis for the use of this terminology may be explained by referring to Figure 5-6, taken from the General Motors suspension request documentation.

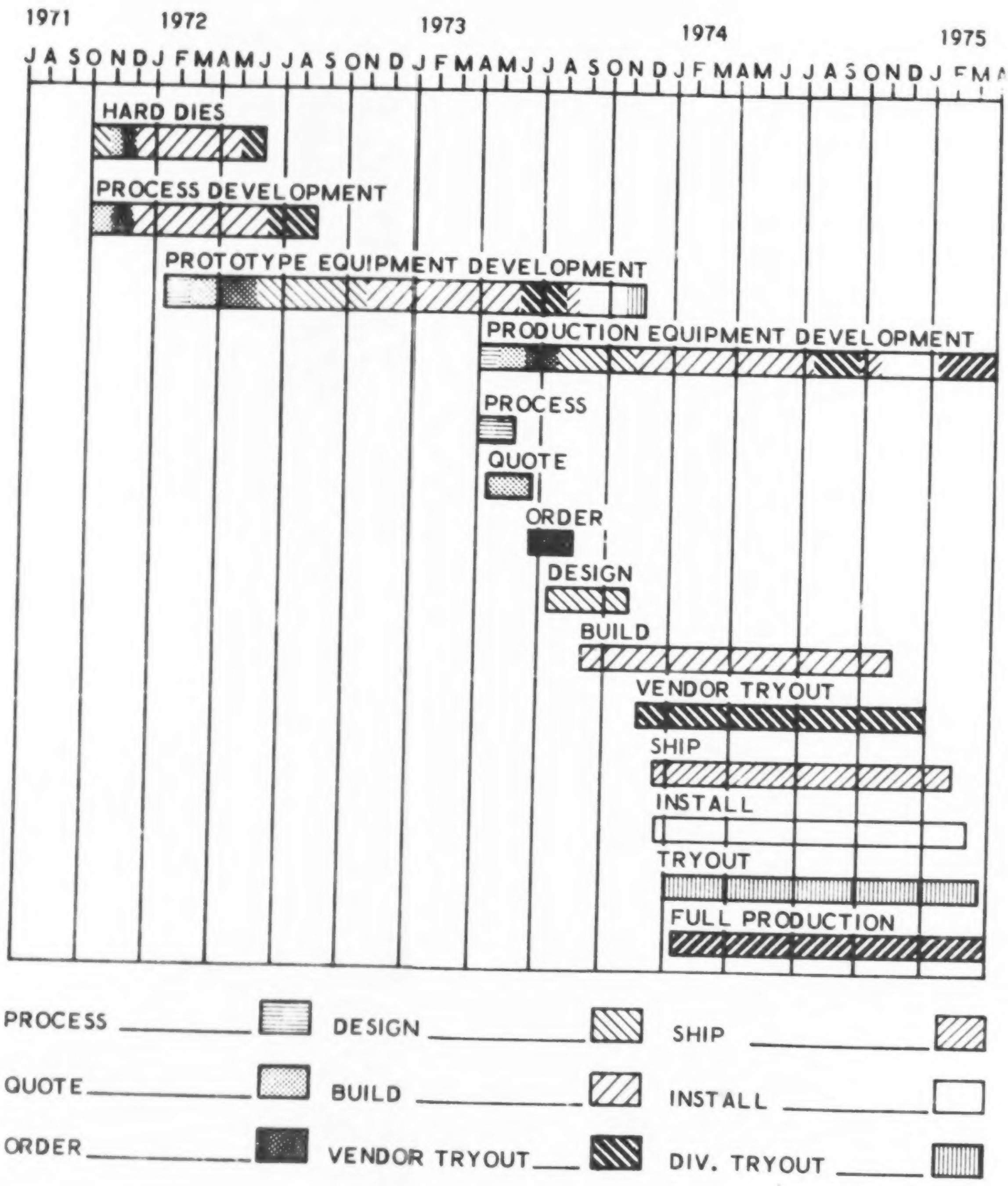


Figure 5-6. General Motors Process Development and Manufacturing Time Table for Under-Floor Oxidizing Catalytic Converter ("Normal" Schedule)

Figure 5-6 displays the overall process steps and activities involved in getting the under-floor catalytic converter into production. This schedule represents near-normal timing for the introduction of a new device to production, except that the Production Equipment Development phase, shown as a 24-month duration, reflects the application of a strong overtime effort. The "normality" of the schedule is primarily characterized by the fact that the Production Equipment Development phase is launched after the prototype assembly line Build activity is well under way and satisfactory operation of some of the equipment has been verified. At this point, the Process activity commences, shown in Figure 5-6 at the April 1973 date. This normal sequence of events, it will be noted, carries the setup of production line equipment out to April of 1975, well past the 1975 model year (Vehicle Job No. 1) production target date.

To meet the 1975 model deadlines, General Motors is now targeted to the schedules displayed in Figures 5-2 and 5-3. Figure 5-2, the schedule for the under-floor catalytic converter, is a "compressed" version of the normal schedule discussed above, showing only the Production Equipment Development phase. It will be noted that the Process activity in this schedule is initiated in August 1972 compared with April 1973 in the normal schedule. Other activities are similarly advanced; for example, the Build activity moves from August 1973 in the normal schedule to January 1973 in the compressed schedule.

In reference to the compressed schedule timing, General Motors has stated that this is the worst possible way to set up for production, noting that (a) tool suppliers have to begin fabrication about 6 months before prototype equipment build is complete and, (b) much of the production line has to be built and installed before the full prototype line is tested. This approach is accompanied by high risks, involving the possibility of having to redesign and rebuild the assembly equipment. Further, General Motors states that the accelerated schedule calls for considerable overtime work for itself and its suppliers and demands compromises allowing less automation and requiring higher labor input. Because of these conditions, the canister will cost more than one designed and built in a normal manner. Generator Motors further emphasized that commitments had to be met for the production equipment, even though there was no assurance from the results of its development tests that the emission standards could be met.

5.1.2 Major Elements in the Schedule

5.1.2.1 Major Elements for the Catalytic Converter

The major elements of General Motors production schedule will be discussed with explicit reference to those systems having a major impact on production lead time. As discussed earlier, one of these systems is the catalytic converter.

After an intensive design development and selection program, General Motors arrived at what it believed to be a satisfactory (under-floor) catalytic converter design in mid-January 1972. At this point, the proper manufacturing method had to be selected. General Motors has defined certain steps which must be followed in order to get into production with a new device involving new materials and new assembly techniques. These steps include the firming up of the design of the product, the building of sample parts on preliminary dies, the development of the process for assembling these parts on mockup assembly equipment, the design and build of prototype production equipment based on what is learned from the mockups, and operation of the prototype assembly line to make sure that the job will be accomplished properly. In a system such as the catalytic converter canister assembly, this sequence is planned to take about 26 months of continuous effort, even on an overtime basis. When the last phase of this process development, the prototype equipment development stage, is far enough under way to permit decisions on the design of the final production equipment, these designs are incorporated in a set of process equipment specifications. This point then defines the start of activities referred to by General Motors as production equipment development. In Figure 5-2, this date is August 1972.

The major steps involved in General Motors production equipment development phase, from product release to production, are as follows:

a. Process
b. Quote by vendor
c. Order
d. Design
e. Build
f. Vendor tryout
g. Ship
h. Install and try out
i. Full tryout for production startup

The details of the activities within each major step are delineated below.

a. Process

Prepare manufacturing and process specifications

1. Describe the sequence of operations.
2. Establish the process to be used for each operation.
3. Describe the work to be done.
4. Identify the type of equipment to be used.
5. Identify the tools to be used.
6. Identify the inspection equipment to be used.
7. Identify the gauges to be used.

Prepare requests for quotation.

1. Describe the operation to be performed.
2. Describe the engineering concept to be used.
3. Specify the equipment cycle time.
4. Specify standards for drives and motors, electrical, hydraulic, pneumatic, lubrication, safety, noise, etc.
5. Describe the method for loading parts -- manual, semi-automatic, or automatic.
6. Describe the inspection stations required.

7. Indicate the approximate size of equipment.
8. State delivery requirements.

Evaluate sources with purchasing.

1. Review the type of equipment required.
2. Consider the number of machines required.
3. Evaluate source capabilities -- facilities, engineering, past record, etc.

b. Quote by Vendor

1. Prepare engineering concepts.
2. Prepare sketches or drawings.
3. Get quotes from their suppliers.
4. Request allowable deviations from AC Spark Plug standards or concept.
5. Compile costs of purchased components.
6. Estimate the cost of engineering and design.
7. Break down the costs of basic machine, electrical controls, hydraulics, hoppers, noise controls, and tools.
8. State the delivery date of unit or units.

c. Order

1. Review all quotations for compliance with basic engineering concepts, with cycle times, with AC Spark Plug and General Motors standards, and with delivery dates.
2. Select a Source (review quotation with production engineering, manufacturing development engineering, works engineering, and purchasing).
3. Prepare a shop order and necessary forms. Circulate to electrical, hydraulic, pneumatic, lubrication, works engineering, and accounting departments for approval.
4. Issue a purchase order.

d. Design

1. Lay out the basic machine concept.
2. Review with AC Spark Plug for preliminary approval.

3. Order long lead items.
4. Complete machine layouts.
5. Review with AC Spark Plug for design approval.
6. Complete design of tooling, hoppers, and feeders.
7. Review with AC Spark Plug for build approval.
8. Order all materials and release to floor for build.

e. Build

1. Obtain materials and build details.
2. Complete all electrical, hydraulic, pneumatic, and control drawings.
3. Review with AC Spark Plug for approval.
4. Obtain materials and build controls.
5. Obtain production parts for fit-up of tooling.
6. Check purchased components and assemble.
7. Install controls and wire and pipe.

f. Vendor Tryout

1. Cycle machine for function.
2. Single index parts through machine.
3. Make necessary changes.
4. Automatic cycle machine.
5. Make necessary changes in machines, tools, controls, feeders, and hoppers.
6. Make sample run.
7. Make any further changes necessary.
8. Make sample production run.

g. Ship

1. Receive AC Spark Plug approval.
2. Dismantle.
3. Ship to AC Spark Plug.
4. Reassemble at AC Spark Plug.

h. Install and Try Out

1. Locate in place and provide necessary utilities.
2. Cycle machine for function.
3. Integrate with material handling equipment.
4. Cycle material handling equipment for function.
5. Single index machine and material handling equipment.
6. Make necessary changes to machinery and material handling equipment.
7. Automatic cycle machinery and handling equipment.
8. Make necessary changes.

i. Full Tryout for Production Startup

1. Run all equipment as a complete line.
2. Make necessary changes and improvements necessary to meet production schedules.

Significant schedule milestones for the major steps described above are as follows (see also Figures 5-2 and 5-3):

Production Equipment Developmement Phase Start: August 1, 1972
Build Phase: December 1972 to March 1974 (under-floor)
November 1972 to May 1974 (manifold-mounted)
Installation Phase: July 1973 to May 1974 (under-floor)
June 1973 to June 1974 (manifold-mounted)
Production Startup Phase: mid-June 1974 to July 1, 1974

5.1.2.2 Carburetor Program

The major elements of the new carburetor program are shown in Figure 5-4. These elements are discussed in the following paragraphs.

5.1.2.2.1. Product Engineering - Design and Failure Mode Analysis

This element has a total duration of 14 months, commencing in early 1971. A 2-month design feasibility study is performed, consisting of surveys and laboratory tests to indicate whether preliminary design ideas are practical and producible. Further work is then undertaken to provide individual test samples and develop failure mode and effect analysis for all the features that are anticipated to be incorporated into the new product. More work, extending beyond the finalized design date (not shown in Figure 5-4), must take place to coordinate the specification changes and refinements which evolve from continued testing.

5.1.2.2.2 Testing - Lab Sample and Die Cast Parts Testing

This element has a total duration of 45 months, commencing about July 1971. Initial tests were conducted with model shop samples. Complete sand-cast carburetors were fabricated starting in November 1971, and in May 1972 die-cast sample carburetors were available for test and evaluation. In March 1973, durability carburetors will be built to prove out the carburetor in its entirety.

5.1.2.2.3 Testing - General Driving and Emissions Testing

This element involves road testing of the carburetor designs and has a duration of 38 months. General Motors has been road testing since May 1971. A time allowance for cold, hot, and altitude testing is included in the test timing plan.

5.1.2.2.4 Testing - Field Test and Durability

Field tests of die-cast carburetors for long-range durability will take place in the summer of 1973 and continue throughout 1974.

5.1.2.2.5 Car Division Tests

The car divisions started receiving sand-cast carburetors in February 1972 and first die-cast samples in July 1972 to start their carburetor general evaluation through the winter and spring of 1973. Summer testing and altitude evaluation will be done in the summer of 1973, with general evaluations continuing through the winter of 1973. Testing of production samples will start early in 1974 and will continue throughout the year.

5.1.2.2.6 Production Engineering

The lead times for production engineering shown in Figure 5-4 are for a two-phase, overlapping program covering the 1975/76 model years.

Work on the design, specification, and ordering of long lead time tooling and equipment began in the spring of 1972 and was continuing at the time of this report. General Motors has structured its carburetor program to produce 8000 units per day of the new two-barrel design at the start of 1975 production (milestone in Figure 5-4 identified as initial production). The production engineering lead time for this program is 22 months. An overall time of 34 months is required to get into full production of 30,000 new carburetors per day for 1976.

5.1.2.3 Functional Flow Chart for the New Two-Barrel Throttle Body

Figure 5-7 shows a functional flow chart for the new two-barrel carburetor throttle body. Similar charts exist for other parts of the two-barrel carburetor. Figure 5-7 depicts the inter-relationships for all of the pieces of tooling and equipment that will be required for throttle body manufacture. These are die casting molds, in-line transfer conveyors for machining, assembly conveyors, subassembly dials and fixtures, punch presses, and functional test conveyors.

For purposes of presentation, General Motors has shown all purchase orders starting at the same time. In reality, orders are staggered in such a way that parts flow is in logical sequence with the completion of equipment construction. Thus, total lead time is more than the 64 weeks shown here for test conveyors alone.

The chart allocates a given amount of time for each procedure required to obtain the tooling or equipment. These generally include specification and ordering, design and building, vendor tryout and debug, shipping, installation, and debugging at Rochester Products prior to full volume production.

5.1.3 Company/Vendor Schedule Consistency

With respect to the catalytic converter, General Motors production development schedule for either of its catalytic converter concepts

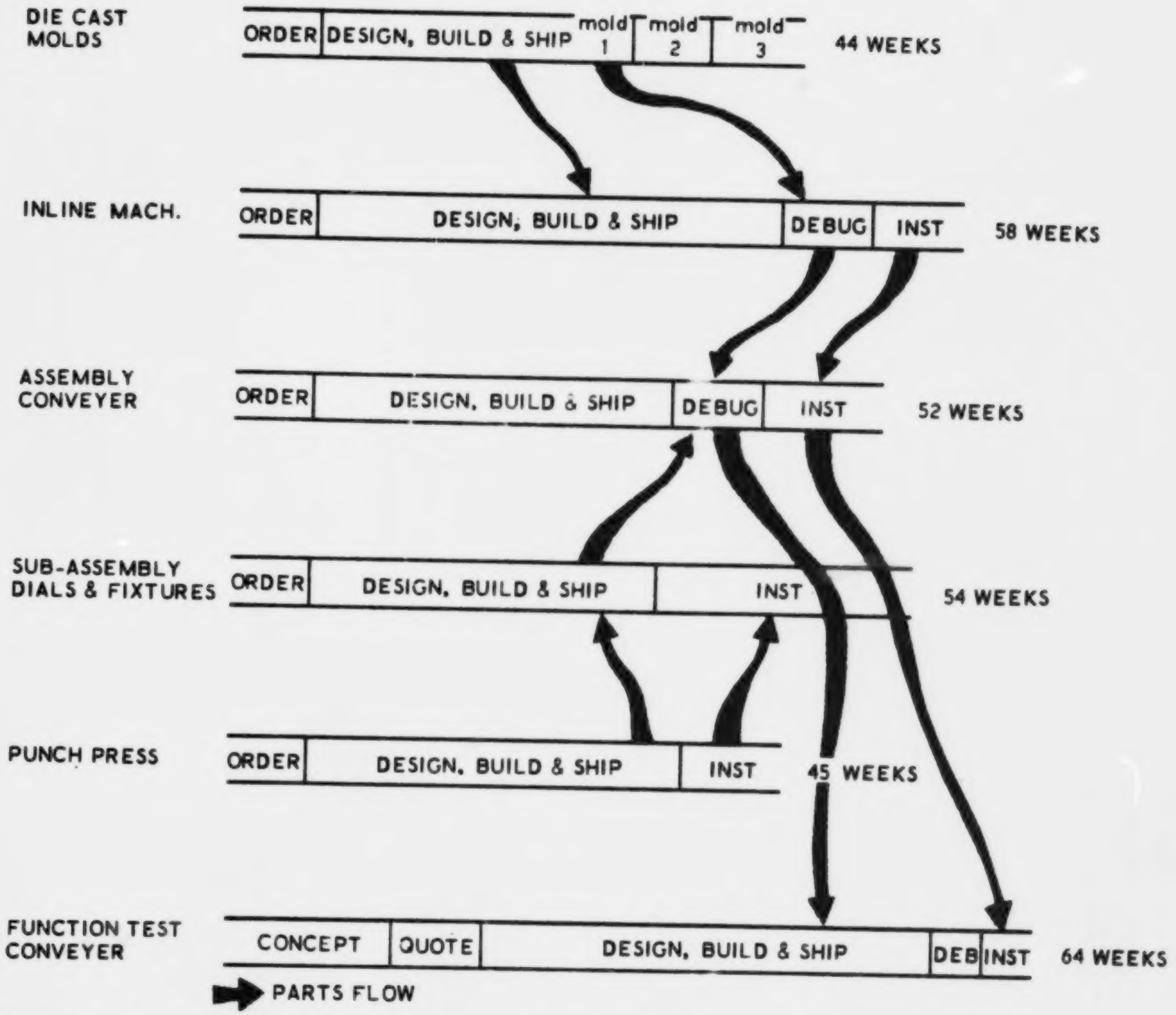

DIE CAST MOLDS
ORDER
DESIGN, BUILD & SHIP
mold 1
mold 2
mold 3
44 WEEKS
INLINE MACH.
ORDER
DESIGN, BUILD & SHIP
DEBUG
INST
58 WEEKS
ASSEMBLY CONVEYER
ORDER
DESIGN, BUILD & SHIP
DEBUG
INST
52 WEEKS
SUB-ASSEMBLY DIALS & FIXTURES
ORDER
DESIGN, BUILD & SHIP
INST
54 WEEKS
PUNCH PRESS
ORDER
DESIGN, BUILD & SHIP
INST
45 WEEKS
FUNCTION TEST CONVEYER
CONCEPT
QUOTE
DESIGN, BUILD & SHIP
DEB
INST
64 WEEKS
PARTS FLOW

Figure 5-7. General Motors Apache Two-Barrel Throttle Body Integrated Lead Time

shows no inconsistency with information received from the catalyst manufacturers. It is noted that a number of the major decision and commitment deadlines regarding catalyst supply had not been met at the time of the visits, and thus some of the early milestones shown in General Motors catalytic converter production schedule would have to be further compressed in order to meet the 1975 production target date. However, based on information obtained from catalyst manufacturers (see Section 6), the production lead time allowance for catalyst plant development probably can be compressed.

The lead time cited by GM for one electron beam welder is 74 weeks. If 9 weeks are subtracted for process and quote times,this leaves 65 weeks from time of order to full production. This checks well with the 52-78 weeks shown in Section 8.3 for a special automated welder plus tooling.

5.1.4 Current and Pending Contractual Agreements

General Motors has $630,000 committed to W. R. Grace for the preliminary design of production line facilities for both monolithic and pellet catalyst plants. No other catalyst-related commitments are known to exist at this time, although preliminary contract negotiations with nine potential oxidation catalyst suppliers are underway.

The platinum-group metal for the catalysts would be obtained from a metal supplier. General Motors is negotiating with a number of platinum-group metal mining companies in South Africa and with the Soviet Union. At the time this report was written, it had made only one new contractual arrangement. This is a contract with Impala Platinum, Ltd., of Johannesburg, South Africa to develop the production capacity to supply General Motors with 300,000 ounces of platinum and 120,000 ounces of palladium per year. Although the Impala Platinum effort right now is in the planning phase, negotiations are in process concerning price, quantity, and delivery schedule. General Motors considers the contract as a statement of its intent to buy the quantities cited. General Motors has contacted other potential suppliers but to date has signed only with Impala Platinum.

General Motors has placed a priority on this issue and a number of decisions are expected to be made very soon such as the actual amount of platinum-group metal to be required each year. Its requirements are fully dependent on the results of current road tests on a cross-section of vehicles with different catalyst loadings of platinum-group metals (0.025 ounce to slightly above 0.1 ounce). Many cars have accumulated 20,000 to 25,000 miles, but the relative deterioration factors must be fully assessed before the requirements can be determined. Also, General Motors requirements must be linked with industry capacity to see if new mines must be opened. An additional consideration is the ability and time required for mining companies to increase current stockpiles of materials.

5.2 FORD MOTOR COMPANY

5.2.1 Overall Schedule

5.2.1.1 Production Schedule

An overall schedule depicting Ford's 1975 model year production development program is shown in Figure 5-8. This schedule combines elements of Ford's timing plans for the vehicle and the engine/emission system, based on schedules and other information provided in its submittal to the April 1972 Suspension Request Hearings and in Ref. 5-1. Key milestones taken from these sources and incorporated in Figure 5-8 are briefly described in the following paragraphs.

Typically, the formal manufacturing program for a given model year car begins with the definition of an overall vehicle package plan 43 months prior to first production. First production usually is targeted for early July to mid-August of the calendar year preceding the model year designation, or at Milestone J in Figure 5-8. This fixes Milestone A, the start date for 1975 model year production development, at January 1971.

As is the case for nearly all emission systems projected for use in 1975 vehicles, Ford's emission package includes an oxidizing catalytic converter. Milestone B (May 1971) represents Ford's initial

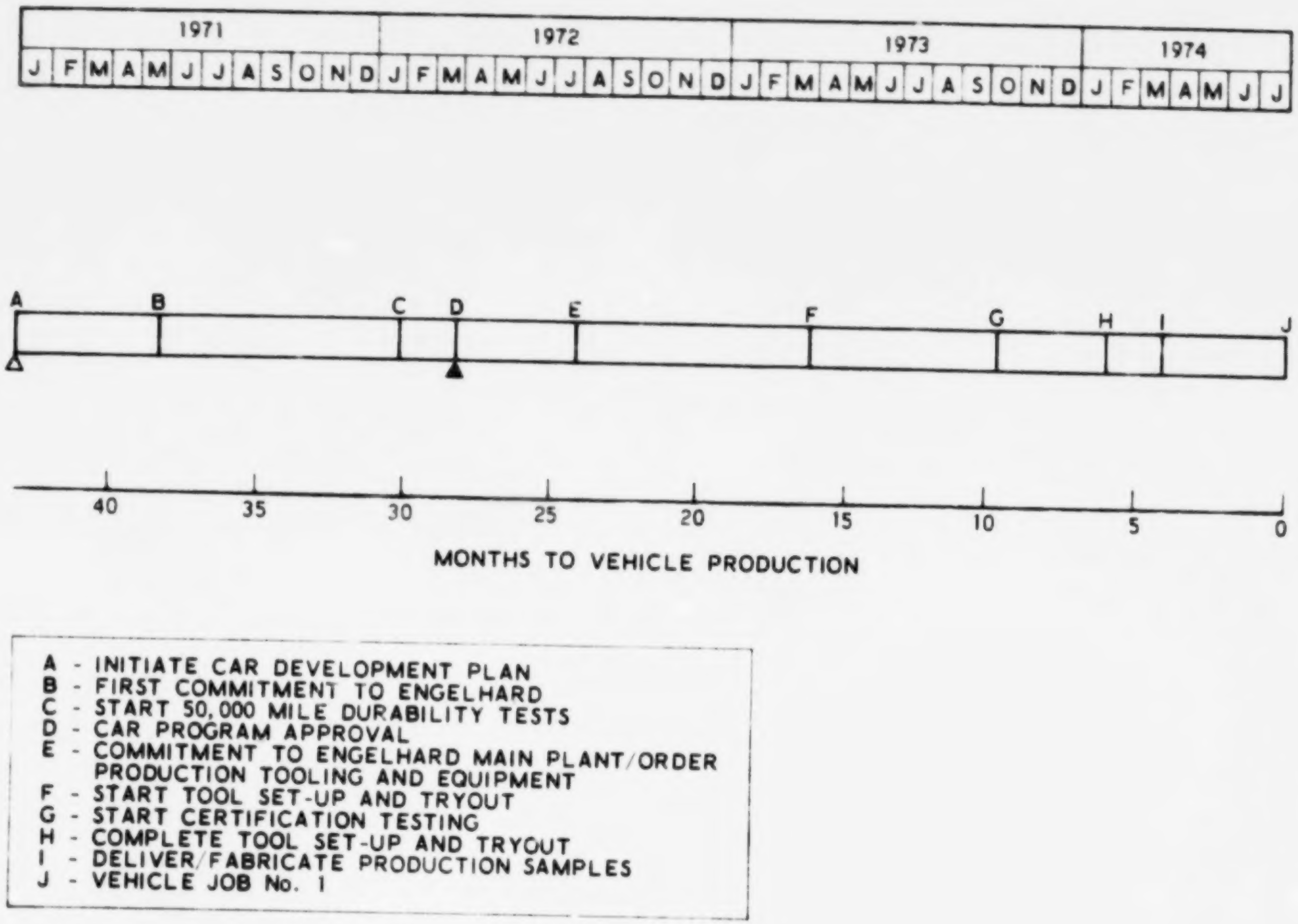


Figure 5-8. Ford Overall Schedule: 1975 Vehicle and Emission Engine Program

commitment to Engelhard covering the development of pilot plant facilities for the production of catalytic converters.

Milestone C (February 1972) identifies the start of Ford's 50,000 mile (Riverside, California) durability test program to evaluate alternate emission control systems. This test program, which is still in progress, will be discussed in greater detail later.

Twenty-eight months prior to Vehicle Job No. 1, at Milestone D (April 1972), the car manufacturing development program started at 43 months is given a final review by Ford management, and approval is issued to proceed with manufacturing development. The program approval point usually signals the beginning of large-scale capital equipment and tooling procurement operations, and is therefore frequently identified with the production lead time requirement, even though some initial capital commitments (for example, Ford's Milestone B) may already have taken place. Ford's 1975 car line programs have been approved on this schedule, even though some car systems are still in the prototype testing phase (catalytic converter emission control systems, for example).

By August, 1972, Milestone E, firm designs for engine and emission systems have been established that form the basis for ordering production tooling and equipment. Milestone E also represents the approval point for the vehicle body design based on the base clay model. Additionally, Milestone E delineates Ford's commitment to Engelhard Industries covering initial construction expenditures for Engelhard's Plant No. 2 or main facility for catalytic converter production operations.

Milestone F (April 1973) identifies the start of major equipment installation on the Ford assembly line. Completion of this operation is scheduled for February 1974, Milestone H.

Milestone G (October 1973) is Ford's target date for starting EPA certification testing.

At Milestone I (April 1974), the last sample part fabrication made to engineering design on the newly acquired and installed equipment is completed. Production samples are then checked for functional fit and performance. Engine production is initiated about 1 month prior to vehicle production, which begins at Milestone J (August 1974).

5.2.1.2 Major Impact Factors

The factors that have major impact on the Ford production schedule can be divided into two categories: (1) production development operations that are common to the manufacture of any model year car line, and (2) 1975-peculiar, emission system-related items.

Factors that appear to be common to any model year car program include most of the production engineering design, equipment and parts procurement, and assembly line development activities that take place following the car program approval milestone. These activities involve the development of process specifications, the evaluation of vendor quotes, vendor selection, equipment/tooling design, and equipment construction, installation, and tryout. An example of an important impact factor in this category would be the lead time required for the procurement and installation of transfer lines, a major assembly line equipment item.

In general, a normal Ford production development program for the complete automobile involves 8 months of production engineering overlapping with 24 months for facilities, equipment, tools, and production proveout. Ford's 1975 production schedule appears to be based on such a normal timing sequence. According to Ford, the 28-month production development lead time allowance for its 1975 car line program is a historically established guideline that provides sufficient time for sound production planning as well as sufficient leeway for the resolution of unpredictable problems that arise in developing the manufacturing process.

With regard to 1975-emission-control-related impact factors, Ford, like other manufacturers, is proceeding with production development based on the use of a catalytic converter emission control system design that is presently unproven with respect to 1975 performance requirements. Program approvals for the 1975 car lines were issued (April 1972) when the

Riverside durability test program had recently been started, and catalytic converter emission system road performance and durability characteristics were largely unknown for the specific designs in test. Normally, a development engineering program culminating in a successful invention would precede the approval milestone event. The Riverside tests are continuing, but, according to Ford, show little promise of meeting the 1975 emission goals.

Ford regards its unilateral decision to proceed with catalytic converter development and production as a "high risk" step that might ultimately be highly disadvantageous financially and schedule-wise if EPA elects to issue interim 1975 standards that might also be met by other control devices such as full-size thermal reactors. According to Ford, the choice of systems could have a serious impact on the engine compartment packaging design, which is usually fixed at 37 months prior to Vehicle Job No. 1. According to Ford, this design milestone is critical because changes in the compartment geometry can progressively impact the entire body structure, starting with the engine cowl and proceeding to the "A" pillars flanking the windshield, the door supports, the overhang, etc. Furthermore, the time is now past the critical point for ordering arc and holding furnaces for foundry operations involved in the manufacture of full-size thermal reactor manifolds for the 1975 model year.

Characteristically high operating and exhaust temperatures associated with catalytic converter operation has led Ford to consider an extensively shielded exhaust system of stainless steel materials. As much as 75 pounds of stainless steel per car may be required, and Ford is concerned about the available supply. Potential suppliers such as International Nickel Company, Inc. have been pressing Ford for estimates of its future requirements, but Ford is unable to provide a forecast of its needs on the basis of prototype testing conducted to date. Stainless steel procurement and its associated vendor lead time requirement may be another Ford schedule impact factor.

5.2.1.3 Critical Lead Time Items

In common with other automobile manufacturers, Ford's critical (pacing) element of lead time concerns the catalytic converter emission control device. The present Riverside test evidence pointing to deficiencies in emission control performance and durability is one factor, already mentioned, that may ultimately stretch out the Ford production schedule by demanding additional development and testing before a final production catalyst design is identified. Aside from this, the controlling item in the Ford schedule is the development of vendor facilities for mass producing catalytic converter hardware.

The critical technical aspect of catalytic converter production appears to be the development of a new mass production technology covering the design, fabrication, and checkout of equipment required for the substrate coating operations, particularly the application of the platinum-group metal catalyst. Only limited-volume batch coating know-how presently exists. In consideration of this problem, Ford entered into an agreement with Engelhard Minerals and Chemical Corporation to underwrite a significant part of the costs for developing a pilot plant facility that could be used to develop the needed technology. Pilot plant equipment procurement was made in March 1972. Using the latter date as a reference, Ford's production schedule (Figure 5-8), calling for the last delivery of production samples at Milestone H (April 1974), would provide about 24 months lead time for developing the mass production processes and associated facilities for catalyzing operations, including the construction, startup and checkout of the Plant No. 2 main production facility. According to Ford, the available time may be only marginally sufficient.

5.2.1.4 Prototype Test Programs

The production development plan incorporates a number of vehicle prototype test programs, the results of which can impact the overall car development schedule at several different levels of significance. These programs include emission system prototype durability tests, mechanical prototype car tests, engineering prototype car tests, and EPA certification tests.

Ford's prototype emission system durability tests were initiated on February 1, 1972. This is a two-phase program utilizing 44 vehicles: 32 vehicles are being tested at Riverside, California and 12 vehicles at Dearborn, Michigan. Phase I is a 50,000-mile durability study to determine system/component deterioration factors. Phase II will determine 4000-mile emission levels, which, in conjunction with the deterioration factors from Phase I, will be used to project certification emission capabilities of the candidate emission systems under test.

Vehicles used for this test program are production 1972 vehicles modified to include the appropriate exhaust system for use with reactor manifolds and/or oxidizing catalytic converters (Engelhard PTX platinum-group metal monolithic type). Additionally, the test vehicles are equipped with secondary air injection, breakerless ignition, advanced carburetors, and exhaust gas recirculation. There are several emission system component combinations undergoing evaluation: Group I vehicles are equipped with a single catalytic converter; Group II vehicles are equipped with thermal (manifold) reactors and two catalytic converters in series; Group III vehicles are equipped with two converters in series without the thermal reactors. A Group IV vehicle set is equipped with a second generation version of the basic Group I system.

Of the systems described above, Ford favors the single catalytic converter without reactors on the basis that it has a minimum impact on front end packaging and controls emission about as well as any of the other systems at substantially less cost. At mid-year, the possibilities for further performance improvement of this system looked good, and testing is planned to be continued through November or December. However, results accumulated as of mid-September indicate that the 1975 standards are not attainable. In addition, a substrate cracking problem in the Group IV vehicles has been observed.

With regard to production scheduling, the timing of the prototype emission system durability test is, in Ford's opinion (shared by other automobile manufacturers), highly extraordinary in that it penetrates well into the production development phase of the manufacturing schedule and provides no assurance of yielding a satisfactory design. In normal practice, an advanced engineering development program would have been conducted, a suitable invention would have been created, and the newly invented system would then be turned over to production engineering for refinement and modification into a production design version. This event would have occurred at a point possibly 4 months prior to the program approval milestone. Under present conditions, Ford's options in the event that the Group I system fails to meet the 1975 emission standards are (1) to postpone the 1975 production target date in order to allow additional time for emission system development, or (2) to re-petition for a suspension of the 1975 standards.

Mechanical and engineering prototype tests are common to nearly all automotive manufacturing development programs. First mechanical prototype car build appears in the Ford schedule at July 1972 (Figure 5-9) about 24 months before Vehicle Job No. 1. The mechanical prototype vehicle is representative of the final car product in the floor pan, chassis, and dash panel areas. It represents the first time all subsystems are operated together to test interactions between working components. Mechanical prototype tests include hot weather, altitude, performance, economy, cooling, and durability road tests, as well as cold weather and octane laboratory tests. Preliminary design parts and systems are periodically replaced by later designs, and refinements are made until the mechanical prototype systems reach a production design level. Normally, major changes in system design are not required, and unplanned impacts on the production schedule are usually minor. Ford schedules the mechanical fit and function signoff (approval) in June 1973.

Engineering prototype tests are conducted about 13 months prior to Vehicle Job No. 1. The engineering prototype is totally representative of the final car product in all areas, and is used to structurally test body sheet metal, to continue the test and development of mechanical features, and to generally prove out all of the car systems in a duty cycle designed to encompass all of the conditions encountered in customer driving service. The test conditions include rough road operation, city traffic, hot and cold weather tests,

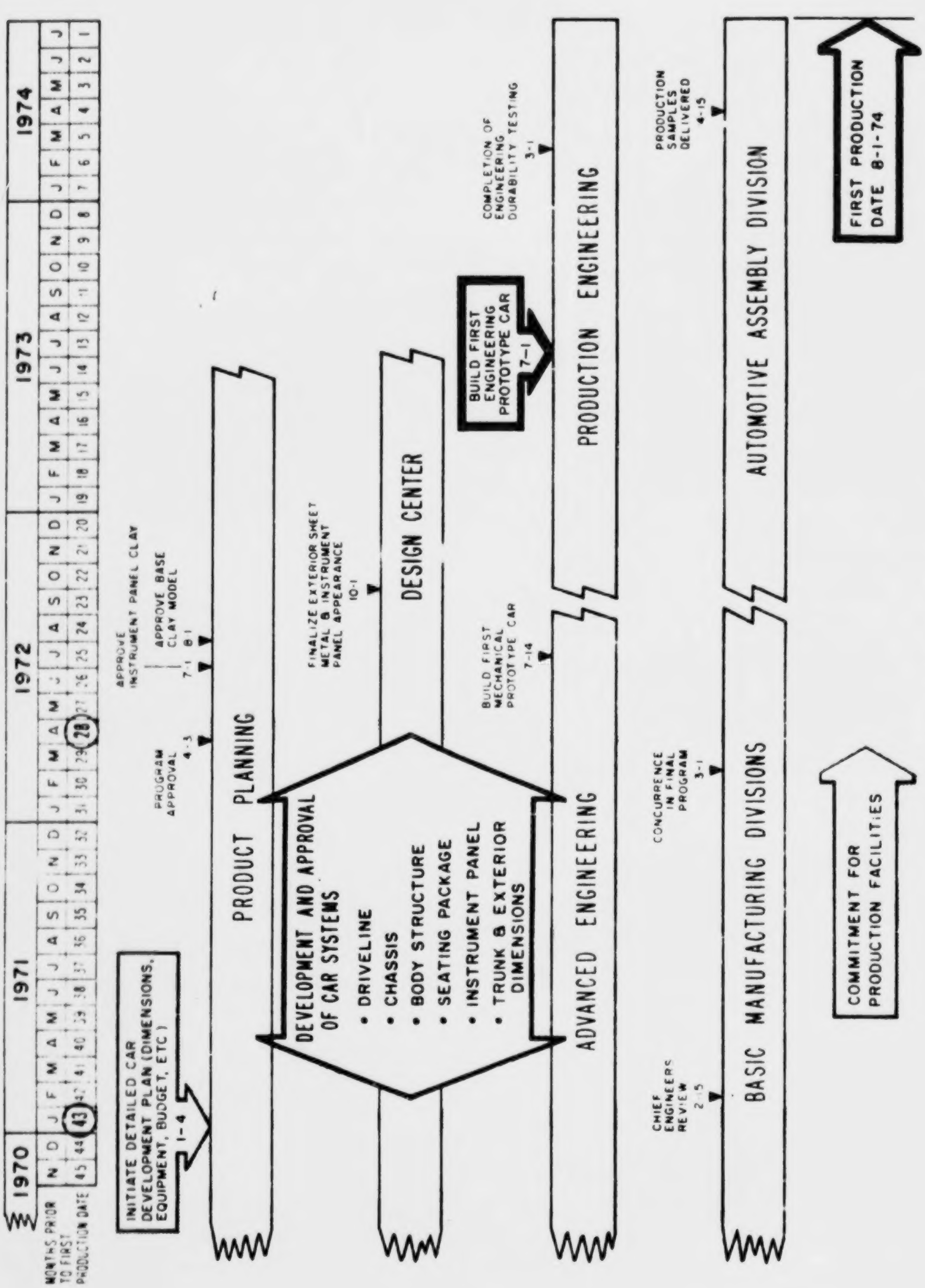

MONTHS PRIOR TO FIRST PRODUCTION DATE
1970
1971
1972
1973
1974
N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J
45 44 43 42 41 40 39 38 37 36 35 34 33 32 31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1
INITIATE DETAILED CAR DEVELOPMENT PLAN (DIMENSIONS, EQUIPMENT, BUDGET, ETC) 1-4
PROGRAM APPROVAL 4-3
APPROVE INSTRUMENT PANEL CLAY 7-1
APPROVE BASE CLAY MODEL 8-1
PRODUCT PLANNING
DEVELOPMENT AND APPROVAL OF CAR SYSTEMS
• DRIVELINE
• CHASSIS
• BODY STRUCTURE
• SEATING PACKAGE
• INSTRUMENT PANEL
• TRUNK & EXTERIOR DIMENSIONS
FINALIZE EXTERIOR SHEET METAL & INSTRUMENT PANEL APPEARANCE 10-1
DESIGN CENTER
BUILD FIRST MECHANICAL PROTOTYPE CAR 7-14
ADVANCED ENGINEERING
BUILD FIRST ENGINEERING PROTOTYPE CAR 7-1
PRODUCTION ENGINEERING
COMPLETION OF ENGINEERING DURABILITY TESTING 3-1
CHIEF ENGINEERS REVIEW 2-15
CONCURRENCE IN FINAL PROGRAM 3-1
BASIC MANUFACTURING DIVISIONS
PRODUCTION SAMPLES DELIVERED 4-15
AUTOMOTIVE ASSEMBLY DIVISION
COMMITMENT FOR PRODUCTION FACILITIES
FIRST PRODUCTION DATE 8-1-74

Figure 5-9. Ford 1975 Car Line Program

and high altitude road tests, some of which are run at the Michigan Proving Ground, the Arizona Proving Ground, and Pike's Peak, Colorado. These tests constitute a much more severe evaluation of the emission control system than the EPA certification durability test. The Ford schedule calls for completion of engineering prototype durability testing in March 1974.

Ford will submit required data for EPA certification tests, including vehicle and emission system descriptions and projected sales data, along with sample hardware to EPA for their approval to start final durability and certification tests in October 1973 (Milestone G, Figure 5-8).

Practically speaking, the rate of mileage accumulation in the durability certification test process is limited (400 or less miles per day, average). Therefore, Ford has scheduled a total of 5-1/2 months for the durability (50,000 mile) phase of the test program (regarded as a minimum allowance) and, on this basis, plans to complete this phase on April 1, 1974. Tests of the emission data (4000 mile) vehicle fleet are scheduled to start in March 1974. Ford has stated that this schedule requires the concurrent (overlapping) testing of the emission data and durability data vehicles, and provides no allowance for re-engineering of systems in event that durability deterioration factors are worse than projected.

5.2.1.5 Schedule Compression

Figure 5-10 shows two versions of Ford's emission system production development schedule. The schedule in the upper half of the figure, designated "normal", was abandoned because of the failure of some components encountered in an earlier experimental durability development test program. This same plan, it may be noted, was once referred to as a "high risk" plan (Ref. 5-1) on the basis that Ford had to start production engineering design several months prior to the availability of a proven invention; that is, at the milestone identified as "12-1, Preliminary Design Assumptions." The lead time indicated in this plan is measured from this milestone and is shown as 32 months.

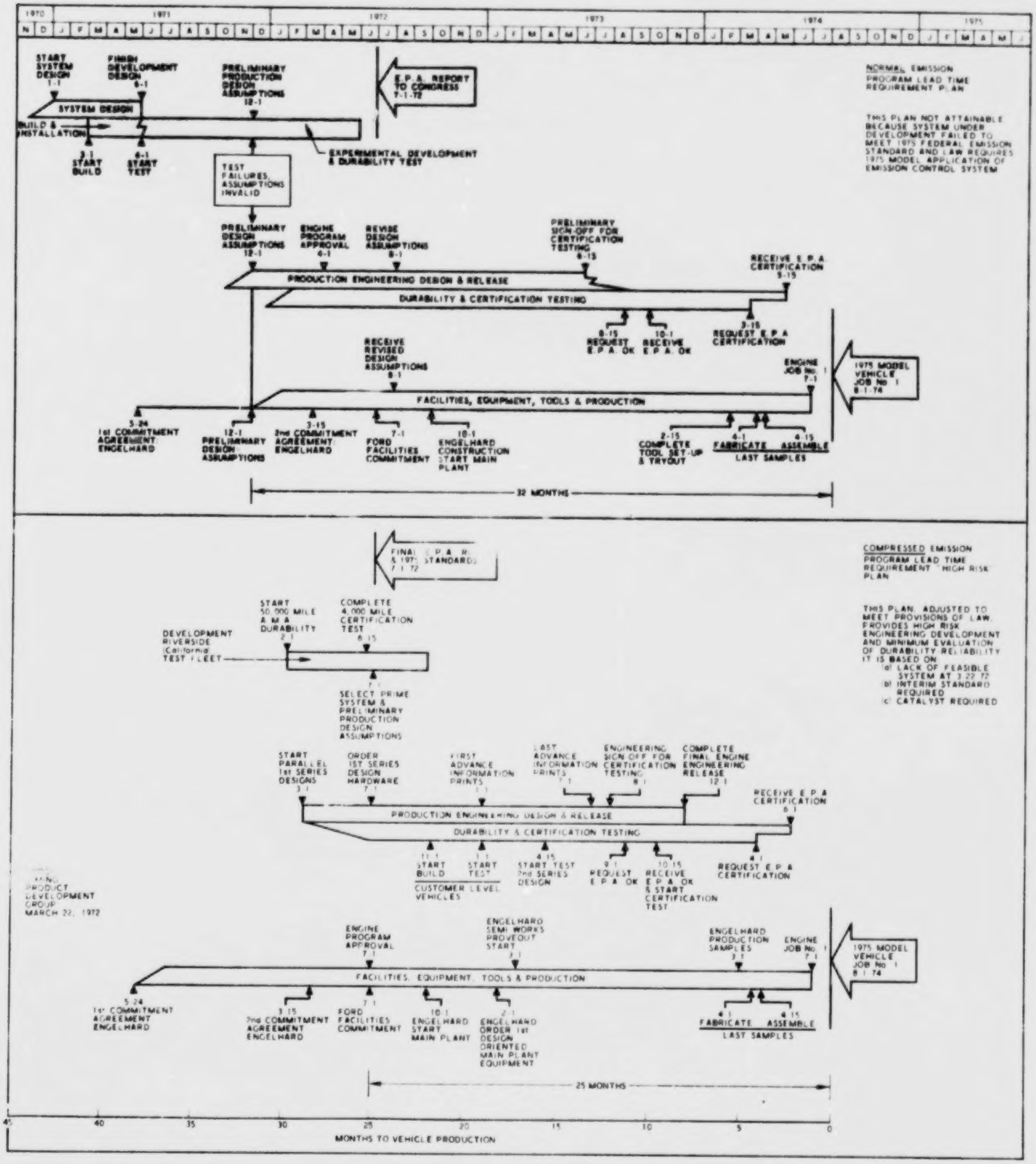

1970
1971
1972
1973
1974
1975
START SYSTEM DESIGN 1-1
FINISH DEVELOPMENT DESIGN 6-1
PRELIMINARY PRODUCTION DESIGN ASSUMPTIONS 12-1
E.P.A. REPORT TO CONGRESS 7-1-72
SYSTEM DESIGN
BUILD & INSTALLATION
3-1 START BUILD
4-1 START TEST
EXPERIMENTAL DEVELOPMENT & DURABILITY TEST
TEST FAILURES, ASSUMPTIONS INVALID
NORMAL EMISSION PROGRAM LEAD TIME REQUIREMENT PLAN
THIS PLAN NOT ATTAINABLE BECAUSE SYSTEM UNDER DEVELOPMENT FAILED TO MEET 1975 FEDERAL EMISSION STANDARD AND LAW REQUIRES 1975 MODEL APPLICATION OF EMISSION CONTROL SYSTEM
PRELIMINARY DESIGN ASSUMPTIONS 12-1
ENGINE PROGRAM APPROVAL 4-1
REVISE DESIGN ASSUMPTIONS 8-1
PRELIMINARY SIGN-OFF FOR CERTIFICATION TESTING 6-15
RECEIVE E.P.A. CERTIFICATION 5-15
PRODUCTION ENGINEERING DESIGN & RELEASE
DURABILITY & CERTIFICATION TESTING
8-15 REQUEST E.P.A. OK
10-1 RECEIVE E.P.A. OK
3-15 REQUEST E.P.A. CERTIFICATION
RECEIVE REVISED DESIGN ASSUMPTIONS 8-1
ENGINE JOB No. 1 7-1
1975 MODEL VEHICLE JOB No. 1 8-1-74
FACILITIES, EQUIPMENT, TOOLS & PRODUCTION
5-24 1st COMMITMENT AGREEMENT: ENGELHARD
12-1 PRELIMINARY DESIGN ASSUMPTIONS
3-15 2nd COMMITMENT AGREEMENT: ENGELHARD
7-1 FORD FACILITIES COMMITMENT
10-1 ENGELHARD CONSTRUCTION START MAIN PLANT
2-15 COMPLETE TOOL SET-UP & TRYOUT
4-1 FABRICATE
4-15 ASSEMBLE
LAST SAMPLES
32 MONTHS
FINAL E.P.A. R. & 1975 STANDARDS 7-1-72
COMPRESSED EMISSION PROGRAM LEAD TIME REQUIREMENT "HIGH RISK" PLAN
THIS PLAN, ADJUSTED TO MEET PROVISIONS OF LAW, PROVIDES HIGH RISK ENGINEERING DEVELOPMENT AND MINIMUM EVALUATION OF DURABILITY RELIABILITY. IT IS BASED ON:
(a) LACK OF FEASIBLE SYSTEM AT 3-22-72
(b) INTERIM STANDARD REQUIRED
(c) CATALYST REQUIRED
START 50,000 MILE A.M.A. DURABILITY 2-1
COMPLETE 4,000 MILE CERTIFICATION TEST 8-15
DEVELOPMENT RIVERSIDE (California) TEST FLEET
7-1 SELECT PRIME SYSTEM & PRELIMINARY PRODUCTION DESIGN ASSUMPTIONS
START PARALLEL 1st SERIES DESIGNS 3-1
ORDER 1ST SERIES DESIGN HARDWARE 7-1
FIRST ADVANCE INFORMATION PRINTS 1-1
LAST ADVANCE INFORMATION PRINTS 7-1
ENGINEERING SIGN OFF FOR CERTIFICATION TESTING 8-1
COMPLETE FINAL ENGINE ENGINEERING RELEASE 12-1
RECEIVE E.P.A. CERTIFICATION 6-1
PRODUCTION ENGINEERING DESIGN & RELEASE
DURABILITY & CERTIFICATION TESTING
11-1 START BUILD
1-1 START TEST
CUSTOMER LEVEL VEHICLES
4-15 START TEST 2nd SERIES DESIGN
9-1 REQUEST E.P.A. OK
10-15 RECEIVE E.P.A. OK & START CERTIFICATION TEST
4-1 REQUEST E.P.A. CERTIFICATION
PRODUCT DEVELOPMENT GROUP MARCH 22, 1972
ENGINE PROGRAM APPROVAL 7-1
ENGELHARD SEMI WORKS PROVEOUT START 3-1
ENGELHARD PRODUCTION SAMPLES 3-1
ENGINE JOB No. 1 7-1
1975 MODEL VEHICLE JOB No. 1 8-1-74
FACILITIES, EQUIPMENT, TOOLS & PRODUCTION
5-24 1st COMMITMENT AGREEMENT ENGELHARD
3-15 2nd COMMITMENT AGREEMENT ENGELHARD
7-1 FORD FACILITIES COMMITMENT
10-1 ENGELHARD START MAIN PLANT
2-1 ENGELHARD ORDER 1st DESIGN ORIENTED MAIN PLANT EQUIPMENT
4-1 FABRICATE
4-15 ASSEMBLE
LAST SAMPLES
25 MONTHS
45
40
35
30
25
20
15
10
5
0
MONTHS TO VEHICLE PRODUCTION

Figure 5-10. Ford 1975 Model Federal Emission Program and Passenger Car Timing Plan

The schedule in the lower half of Figure 5-10, designated as "compressed" and "high risk", is Ford's current emission system timing plan. This plan, it may be noted, is identical to the schedule submitted as Exhibit 4-8a in the Ford suspension request submittal in April 1972, which was targeted to the establishment of interim Federal standards requiring the use of catalytic converters. The term "high risk" as used here refers to the lack, as of March 22, 1972, of a feasible system or proven invention relative to Ford's proposed interim standards and to the durability requirements specified by the Federal Clean Air Act of 1970.

In the current Ford emission system production development schedule, the lead time is measured from the Prime System Selection/ Preliminary Production milestone dated July 1, 1972, and is shown to be 25 months, compared with 32 months in the "normal" plan. The numbers indicate a reduction of 7 months; hence the use of the term "compressed" in the current schedule. Note, however, that all of the milestones pertaining to facilities, equipment, tools, and production are unchanged between the "normal" and "compressed" plans. In view of the fact that the facilities requirement for catalytic converter production paces Ford's timing, it would appear that the term "compressed" simply reflects a slip in the program start or schedule reference point. This lead time reference point of 25 months for the emission control system and engine occurs 3 months later than the reference lead time (28 months) for the complete automobile.

According to Ford, they have had no previous experience applicable to schedule compression for emission control systems and do not know what a compression plan might cost. A case of schedule compression occurred on their 1973 Ford/Mercury bumper development program. On this program, Ford had to proceed with production development before National Highway Traffic Safety Agency standards were officially released. Unexpected changes in the regulations, when issued, caused design modifications that delayed Clay Approval and Engineering Prototype Build by about 16 weeks. The points of slippage occurred at about 23 and 13 months before Vehicle Job No. 1, respectively. The cost of this slippage was quoted as 25 to 30 million dollars, of which nearly half was due to major engineering changes in tooling.

5.2.2 Major Schedule Elements

5.2.2.1 Introduction

Details of the Ford schedule for 1975 model year production are most conveniently presented in two major categories: (1) Ford's car line program, and (2) Ford's engine/emission system program. These schedules are discussed in the following paragraphs.

5.2.2.2 Ford Car Line Program

The target date for production of the first vehicle off the assembly line, Vehicle Job No. 1, varies among different Ford lines from early July to mid-August. August 1 is used as a representative date. A typical car line development program is shown in Figure 5-9.

The development of an overall package plan for a given car is initiated 43 months prior to Vehicle Job No. 1. The initial phase of this effort establishes the broad objectives for the product design, including performance levels sought, overall size, styling goals, equipment to be included, and cost.

At 40 months prior to Vehicle Job No. 1, the driveline selection has been finalized and the chassis and hood dimensions are defined.

At 37 months, the body structure is finalized and the complement of equipment to be packaged in the engine compartment is delineated. According to Ford, this is an extremely critical milestone because possible changes in the engine compartment geometry can progressively impact the entire body structure.

At 33 months, preliminary designs for the instrument panel, front compartment, and seating package are delineated. These designs are finalized at 28 months. Also at 33 months, the design of a first mechanical prototype vehicle begins (the mechanical prototype incorporates all of the structural and chassis equipment aspects of the vehicle). All dimensions needed to package the components for a working vehicle are defined.

The development initiated at 43 months continues through to the 28-month milestone, with management reviewing and approving the selected designs for the various car systems (driveline, chassis, body structure, etc.) on a continuing basis. At 28 months, management makes a final overall review of the program and issues approval to proceed with manufacturing development. As mentioned earlier, this is a key point in the program, signaling management's decision to commit major program funds to the continuation of the product development effort.

At 24 months, a final approval of the exterior car styling is made (Base Clay Model Approval). Also at 24 months, production engineering design (order) of long lead parts and tools (nonengine) is started. Concurrently, work starts on the acquisition of prototype parts for the assembly of full engineering prototype vehicles. The first engineering prototype build and test occurs at about 13 months (July 1, 1973). The prototype build and test program continues, with car systems successively updated, until designs at the production level are attained. Vehicle function and fit signoff is scheduled in mid-February 1974, 5-1/2 months before Vehicle Job No. 1.

Production engineering design and drawing release continues through mid-January 1974 (7 months) when the last drawing release is issued.

By April 1, 1974, all basic tools must be finished so that sources can fabricate first samples from tools by that date. Ford concurrently starts layout inspection and laboratory examination of these samples.

Production samples of all tooled parts are due at the Ford Automotive Assembly Division by April 15, 1974. The samples are used to check complete vehicles so that all tool-made parts are verified as to fit and performance in a completely assembled car.

By July 15, 1974, vendors and parts suppliers have completed their initial production runs and parts are made available in the Ford assembly plants to start stocking the production line. Vehicle Job No. 1 commences about August 1, 1974.

5.2.2.3 Ford Emission Engine Program

Ford's latest Emission Engine Program is shown in Figure 5-10. To the milestones shown in this figure can be added several more details from Ref. 5-1 and Ford's submittal to the April 1972 Suspension Request Hearings. These items, though not designated in Figure 5-10, are incorporated in the description of the program given in the following paragraphs.

The Riverside/Dearborn development tests initiated on February 1, 1972 (30 months prior to Vehicle Job No. 1) will continue through December 1972 and possibly longer. The selection of a prime system from among the several emission control systems under test was projected for mid-year (July 1, 1972), when the 4000-mile development prototype certification tests were scheduled for completion. Additional information on vehicle prototype testing and scheduling is shown in Figure 5-11.

Parallel design work on the various systems under test was started on March 1, 1972; first series mechanical prototype hardware based on the prime system selection would be ordered on July 1, 1972. Building and testing of these prototypes was scheduled to commence on November 1, 1972 and January 1, 1973, respectively.

First Advanced Information (AI) prints refer to the initial production design specifications leading to engineering prototype vehicle development. Last AI prints would be issued on July 1, 1973 (13 months), which corresponds to the Figure 5-9 milestone designated "Build First Engineering Prototype Car."

Testing of a second series prototype design begins on April 15, 1973 (16 months). The second series design will be equipped with a catalytic converter produced by the Engelhard pilot line facility, and all other new parts will be production prototype category. Prototype testing will continue, with experimental and preliminary components periodically replaced by refined designs. Preliminary engine/emission system/mechanical system function and fit signoff has been scheduled for June 15, 1973 (not designated in figure).

August 1, 1973 (12 months) is the scheduled date for engineering signoff for certification testing, fixing the hardware to be used for the 50,000 mile emission durability fleet. Fleet testing is scheduled to start in October

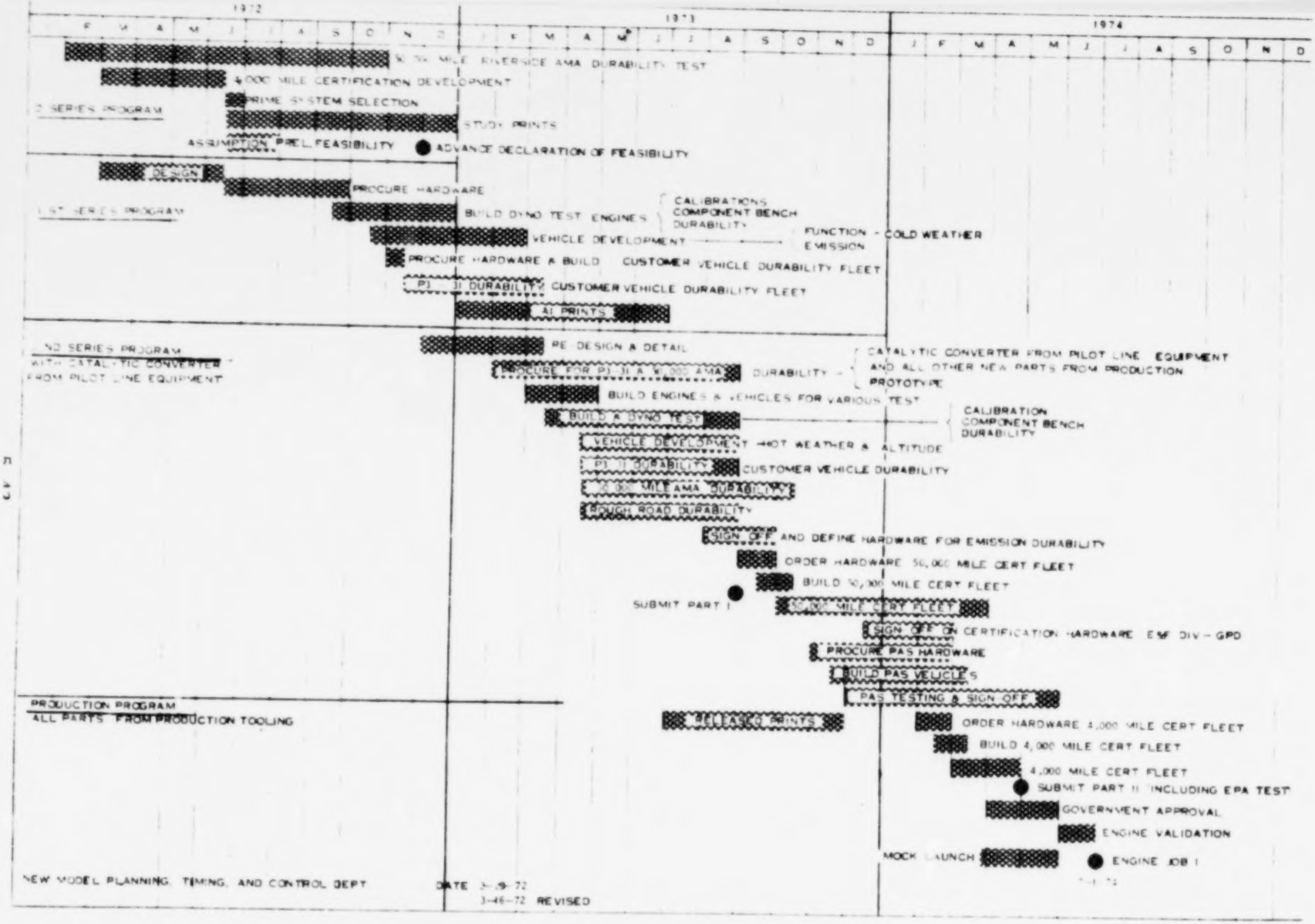


Figure 5-11. Engine/Emission Hardware Testing and Scheduling

and will continue for about 6 months. EPA certification is anticipated on June 1, 1974.

With regard to the facilities/tooling schedule, the first Ford commitment to Engelhard occurred in May 1971 and the second on March 15, 1972. These commitments relate to the development of Engelhard's Plant No. 1 pilot facility. Ford facilities commitments indicated at July 1 refer to additional vendors that may be involved in catalyst manufacture for Ford.

On August 1, 1972 (not shown in figure), Ford made another commitment to Engelhard covering capital investments involved in the construction of Engelhard's Plant No. 2, or main production, facility. Construction of this plant was scheduled to start October 1, 1972.

Ford contract awards for facilities and long lead manufacturing equipment required for Ford-manufactured parts were issued on September 1, 1972 (not designated).

Engelhard main plant design-oriented equipment is scheduled to be ordered on February 1, 1973. First pilot plant output is planned to be available shortly after, on March 1, 1973. Tooling setup and tryout for Ford-produced components has been scheduled to start on April 1, 1973, 16 months prior to Vehicle Job No. 1, and will be completed on February 15, 1974 (not shown in figure). Engelhard catalytic converter production samples are scheduled for availability on March 1, 1974. Last sample parts fabricated on Ford's installed production equipment are made on April 1, 1974 and are assembled on April 15, 1974. Engine Job No. 1 is scheduled for July 1, 1974, one month prior to Vehicle Job No. 1 because the acceleration of engine production is initially somewhat slower than acceleration of vehicle production.

5.2.3 Ford/Vendor Schedule Consistency

With regard to schedule consistency between Ford and its vendors, there are two major elements of the Ford schedule that might be selected for examination: the time allocation for the procurement of long lead equipment and tooling, and the time allocation for the development of vendor facilities for catalytic converter production, the critical or pacing item in the Ford schedule.

Among the longest lead time items in the inventory of possible production equipment required is the transfer line. This equipment performs automatic sequential machining operations on castings such as engine blocks, cylinder heads, transmission components and other parts. It has already been mentioned that 13-1/2 months have been scheduled for the design, construction, delivery, and installation of transfer lines for the 1974 Ford Pinto cylinder heads. Transfer lines for other car line production operations have taken 14 to 16 months for the period from receipt of order until completion of installation (see Section 8. 1).

Another long lead time item of equipment is the high capacity press for cold metal stamping operations (forming, blanking, piercing, etc.). Lead time for this equipment from receipt of order to installation and check-out ranges from 6 to 11 months, depending on the press type (single, double, triple action), capacity, and associated feed and control accessories (see Section 8. 2).

Ford has allocated the period from Milestone E through H (Figure 5-8), or 18 months, for the procurement, installation, and tryout of tools. This would appear to be reasonable, in view of the delivery times quoted above for major items of equipment and the necessity for integrating this equipment in the assembly line process.

The other major schedule item that is useful to examine for consistency is Ford's allocation for the development of vendor facilities for (monolithic) catalytic converter production. There are two basic manufacturing operations and vendor classifications to be considered in this regard: the catalyst manufacturer and the substrate manufacturer. Ford has selected Engelhard as its prime catalyst manufacturer. Other manufacturers that have been considered include Mathey Bishop, Inc., Universal Oil Products Company, and W. R. Grace and Company. One monolithic substrate supplier definitely participating in the manufacture of Ford catalysts is American Lava Corporation. Another possible contender is Corning Glass Works.

Both catalyst and substrate manufacturers have lead time requirements involving, primarily, the construction of new facilities and the development of a production technology required to produce the millions of catalyst devices needed for 1975 automobile production. Figure 5-12 shows the timing requirements supplied to Ford by the various vendors. The data shown have been verified by the testimony and documentary evidence submitted at the April 1972 Suspension Request Hearings and by information acquired in visits to the manufacturers' facilities during the course of the lead time study. It can be seen that the facilities (main plant) construction, tooling, and production timing requirements for the various catalyst manufacturers are reasonably consistent, ranging from 20-1/2 to 23 months. The substrate manufacturers show lead time requirements ranging from 21-1/2 to 23 months. In terms of Ford's production needs, American Lava's lead time requirement might be considerably reduced (see Section 6.1).

The essential data shown in Figure 5-12 have been reproduced in Figure 5-13 for comparison with Ford's overall timing schedule. The milestone designations are the same as shown in Figure 5-8. Milestone E in the Ford schedule is Ford's commitment to the Engelhard main plant, and represents authorization to proceed with plant construction. The Engelhard initiation of production corresponds to Ford's March 1 date for receipt of Engelhard production samples (Figure 5-10). Full Engelhard production by April 1, as scheduled, provides sufficient time for stockpiling catalysts so as to develop production buildup of the canister fabrication either at the Ford plant or at vendor facilities in time for proper inventory buildup and pilot production runs at the Ford Automotive Assembly Division plants.

5.2.4 Current and Pending Contractual Agreements

Known Ford contractual agreements include commitments made to Engelhard relating to catalyzing operations, and commitments made to American Lava relating to substrate manufacture.

The first commitments involving Engelhard concern the development of pilot plant facilities (Plant No. 1) designed to evolve a mass production technology for performing wash coat (alumina) and catalyzing (platinum-group metal) operations on a monolithic substrate supplied by other vendors, e.g., American Lava, Corning. Ultimately, the technology developed in the pilot

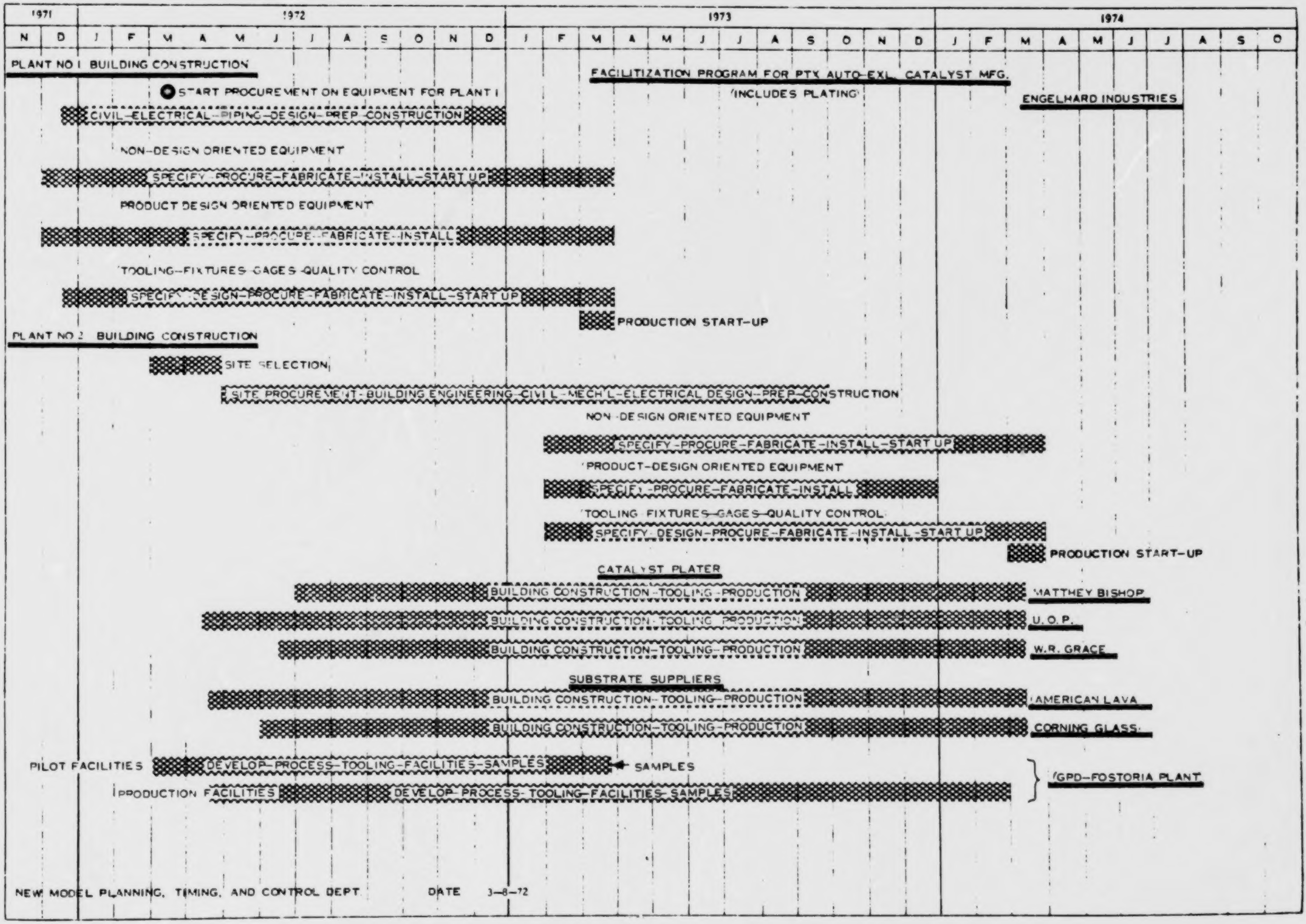
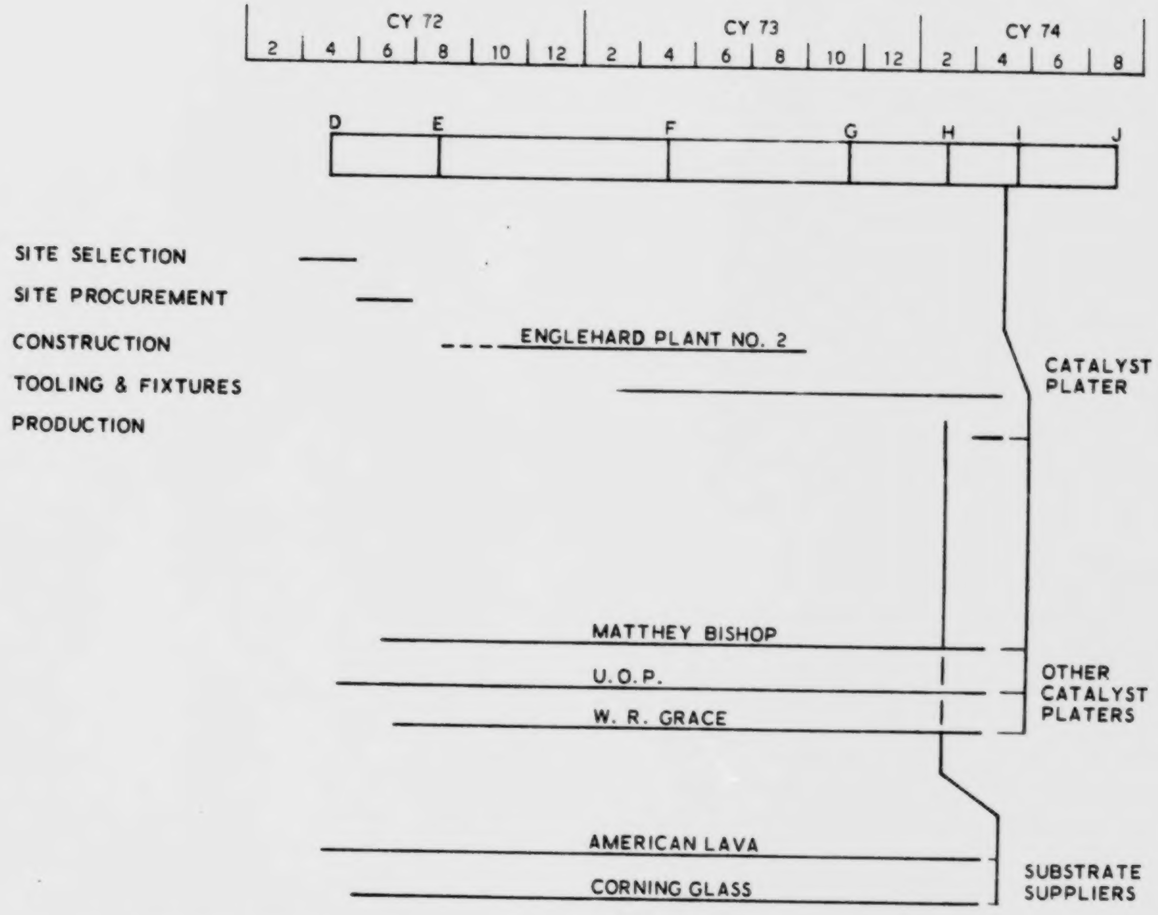


Figure 5-12. Vendor Timing Requirements



D - CAR PROGRAM APPROVAL
E - COMMITMENT TO ENGELHARD MAIN PLANT/ORDER PRODUCTION TOOLING AND EQUIPMENT
F - START TOOL SET-UP AND TRYOUT
G - START CERTIFICATION TESTING
H - COMPLETE TOOL SET-UP AND TRYOUT
I - DELIVER FABRICATE PRODUCTION SAMPLES
J - VEHICLE JOB No. 1

Figure 5-13. Ford Catalytic Converter Program Timing

operation is planned to be incorporated in a main plant production facility (Plant No. 2). The production capacity of the pilot plant (1,500,000 units per year) eventually would be combined with that of the main plant to provide Engelhard's total output capacity. This capacity is not known; however, overall, 3.4 million units per year will be supplied to Ford. Engelhard will wholly own these facilities.

The first Ford commitment agreement concerning Engelhard pilot plant development occurred May 24, 1971 (Figure 5-10). In this agreement, Ford and Engelhard committed funds totaling $2.4 million, presumably for site procurement and initial construction operations. Half of this consisted of (nonrecoverable) Engelhard funds. The next major increment of commitment was made late in March 1972. By June, Ford had committed $4.0 million to the pilot program, of which $3.7 million was direct capital investment guarantees to Engelhard and $300,000 was assigned to American Lava.

On August 1, 1972 Ford made another commitment to Engelhard relating to the development of the main plant facility. The capital involved in this agreement is not known. Ford commitments to Engelhard plant development will rise sharply to about $10 million in March 1973 when product-design-oriented equipment and facilities are purchased, and to $14 million by April 1974.

In addition to the facilities development commitments described above, Ford has a 3-year contract with Engelhard committing it to supply Ford 500,000 troy ounces of platinum per year. The contract was said to be written on a price-protected, no-cost-for-cancellation basis.

As of June 1972, American Lava had a formal commitment from Ford ($300,000) covering its capital expenditures through calendar year 1972 for the scaleup of production facilities to meet a portion of Ford's (Englehard's) substrate requirements. This agreement has been extended (capital commitment unknown) to cover, on a time-phased basis, the development of additional American Lava production capacity through the first quarter of 1974. This is a maximum cancellation agreement (similar to Engelhard's), providing for reimbursement of American Lava's nonrecoverable expenditures in the event of order cancellation. Two production units are covered by contract. The first of these will be completed in the first quarter of 1973, the second in this first quarter of 1974. Each unit has a two-shift capacity of 1.5 million units per year.

As of October 1972, American Lava was negotiating with Ford on a piece-part contract that would guarantee American Lava some minimum quantity of production business. In these negotiations, American Lava had been asked for an "irrevocable, paid-up, royalty-free license in perpetuity" which would permit Ford to manufacture or license other manufacturers to make the American Lava product at some future date.

No other Ford contracts in force have been identified, although it is known that Ford is seeking other substrate manufacturers and has talked with Corning and others. Additionally, Ford is known to be seeking fabricators for the manufacture of the catalyst canister. Walker Manufacturing Company, Arvin Industries, and others have been mentioned as possibilities.

5.3 CHRYSLER CORPORATION

5.3.1 Overall Schedule

Chrysler's proposed 1975 model year emission control system is a best systems choice which incorporates a combination of established or improved devices introduced in previous model years plus some new devices. The chronology related to the introduction of new systems leading to the emission control package projected for 1975 production is shown in Table 5-1. As indicated here, the items presently involved in production development for 1975 are the catalytic converter system; the altitude-compensated, variable venturi carburetor; the electronic spark advance and electronic EGR control; and the frame and body modifications needed to accommodate the catalytic converter device. The manufacturing development schedules for these items are discussed in the following sections of this report.

5.3.1.1 Production Schedules

Figure 5-14 shows Chrysler's overall production development schedule, including the overall lead times for new 1975 emission control components and related items. The longest lead time item is the catalytic converter system which had a production design approval date of April 1972. This milestone is 28 months prior to vehicle production which starts in August 1974. Other milestones shown in Figure 5-14 are discussed in Section 5.3.2.

5.3.1.2 Major Impact Factors

An important milestone in the schedule for the catalytic converter system is the production start date for the assembled converter. Like other automobile manufacturers, Chrysler will subcontract the manufacture of the major components of this device and will assemble the components in-house. Accordingly, its manufacturing development schedule is impacted by the need to coordinate activities among, and exercise interface control between, three separate vendors involved in the converter manufacturing process: the substrate manufacturer, container manufacturer,

Table 5-1. Chrysler Emission Control Modifications for 1970 through 1975 Model Year Production

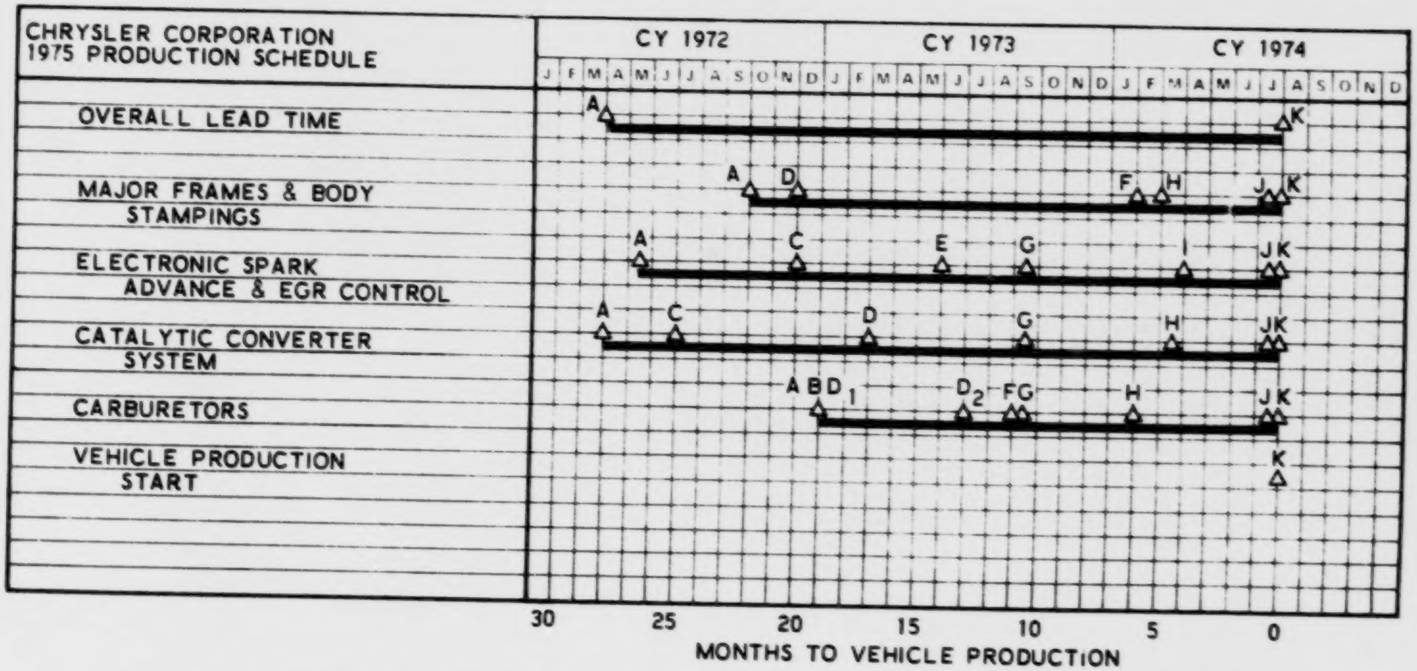
Modifications	Model Year					
	'70	'71	'72	'73	'74	'75
Engine Modifications						
Lower compression ratio	L	L	A	A	A	A
EGR			L	A	A	A
Air injection and exhaust manifold reactor			L	L	L	A
Electric choke				A	A	A
Altitude-compensated, variable venturi carburetor						A*
Electronic Engine Controls						
Electronic ignition		L	L	A	A	A
Electronic spark advance					L+	A*
Electronic EGR control						A*
Catalytic Converter System						
Monolithic catalyst converter						A*
Catalyst converter bypass and bypass valve						A*
Double wall exhaust pipe						A*
Frame and Body Modifications						A*

L - Limited Number of Models

A - All Models

+ - Early Release for some 1974 Imperial Models

* - New for 1975 Models



A - PRODUCTION DESIGN PRELIM. APPROVAL
B - TOOLING & FACILITIES PROGRAM APPROVAL
C - START PRODUCTION PRETEST FROM SOFT TOOLING
D - START PRODUCTION TOOLING
E - LIMITED PRODUCTION START
F - START PRODUCTION SAMPLE BUILD
G - START EPA CERTIFICATION TESTS
H - START VEHICLE PILOT PROGRAM
I - EARLY USE
J - FULL COMPONENT PRODUCTION START
K - START VEHICLE PRODUCTION

NOTE: 1. D_1 - START PROCUREMENT OF DIE CAST DIES

2. D_2 - START OTHER MAJOR TOOLING

Figure 5-14. Chrysler Overall Schedule for the 1975 Emission Control System

and catalyst manufacturer. Furthermore, few of these vendors have had previous experience in an automotive, mass production supply relationship. Potential schedule problems arising from these factors may delay the start of converter assembly.

An additional item of major impact to all systems is the start of the vehicle certification tests. The test vehicles must incorporate all systems that are associated with the operation of the catalytic converter, including engine modifications, electronic controls, frame and body modifications, and related exhaust system modifications. To ensure that the components in test are similar in all material respects to production components, production samples are planned to be delivered earlier than the normally planned pilot runs. With regard to the catalytic converter, Chrysler has selected a platinum-group metal monolithic design, but has not yet finalized the system sufficiently to release a production design specification and place orders for manufacture. This may impact the scheduled start date for certification testing.

Another potential impact factor involves the modifications to the vehicle frame and body which may be required to accommodate the catalytic converter. The Chrysler unibody and torsion bar suspension design features make modifications to the underfloor more complex than in the more conventional, separate frame and body construction. As an example, modifications to the floor pan to make room for the catalytic converter container involve structural modifications of considerable complexity. The torsion bars which are placed under the floor of the car present obstructions to the routing of exhaust and bypass pipes and to the placement of components that go under the floor of the car, and also add to the complexity of the structural modifications.

5.3.1.3 Critical Lead Time Items

The major lead time problems relate to commitments to vendors for the catalyst substrate and catalyst container,which have fallen behind the planned dates. At this time Chrysler is uncertain whether or not it can obtain representative production-type catalytic converters by the start of EPA certification tests in September 1973 and whether volume production of catalytic converters will be available for the vehicle production target date of August 1, 1974. The other 1975 systems appear to be on schedule and no major problems are foreseen.

A contract with UOP was signed in September 1972; however, this contract covers only the production design and development of the catalyzing process; commitments for the construction of a process plant are still pending.

5.3.1.4 Prototype Programs

The prototype test programs for carburetors appear to be under control and no specific problems are apparent. Prototype design of the electronic spark advance and EGR controls has been underway since early in 1972 and the test program for these devices is scheduled to start in December 1972. This particular portion of 1975 emission control prototype testing is also under control.

The major problem in prototype testing relates to the catalytic converter. It had been planned to establish the design by January 1972; however, as of November 1972, prototype testing was still proceeding without success.

5.3.2 Major Elements in Schedule

Details of the schedules shown in Figure 5-14 are presented in Figures 5-15, 5-16, 5-17, and 5-18 for the major frame and body component modifications, electronic spark advance and EGR control, catalytic converter system, and carburetors, respectively. It is the purpose of the following discussion to explain some of the activities and schedule milestones which comprise the manufacturing development lead times required for these systems.

5.3.2.1 Major Frame and Body Components

Details of the schedule milestones pertaining to the lead time requirement for the major frame and body component modifications are presented in Figure 5-15. The lead time indicated is 22 months. It must be noted that the rear quarter panel is one of the longest lead time items in the frame and body category and was used as the basis for detailing the schedule milestones shown in Figure 5-15.

Upon completion and approval of the vehicle body clay, a management decision is made to proceed with production development. For the 1975 model year this decision was made early in October 1972. This decision signals the start of styling drawings. Styling release is scheduled for November 1972. At this point, engineering metal draft drawings are started. Die models for the body panels (both wood and plastic) are due by August 1973. The dies are produced by vendors and are tested at the vendor plant prior to delivery to Chrysler. After delivery, the dies are placed into hydraulic presses in the body panel production line and sample parts are produced to check out the tooling and to produce parts for pilot assembly operations. The date for delivery of the last sample part is March 1974. The sample parts are released to the Chrysler pilot plant by the end of March 1974 and pilot assembly of vehicles is started. Upon completion of pilot production and verification of assembly for all models, full volume production of the frame and body components starts in early July 1974. The frame and

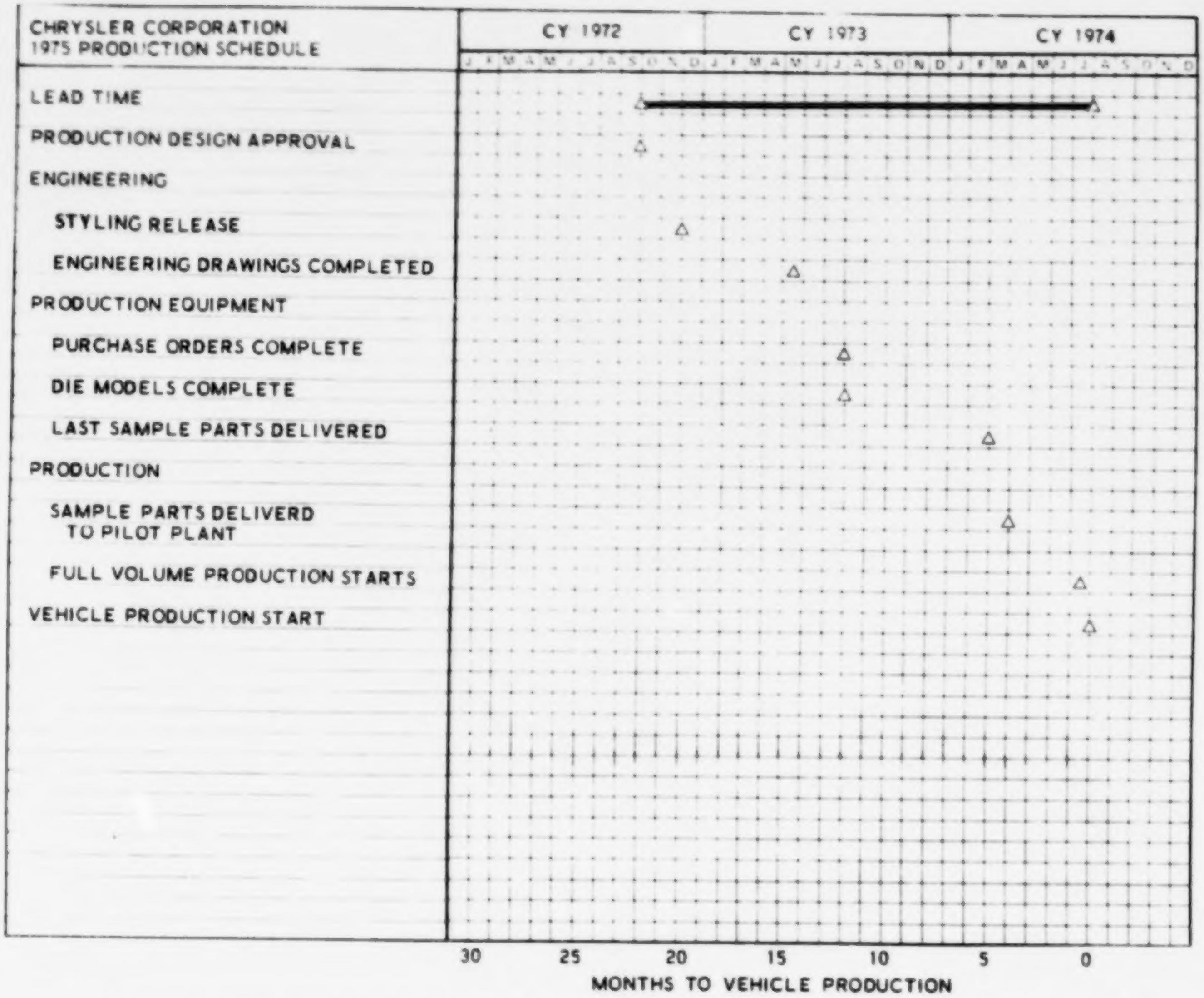


Figure 5-15. Chrysler 1975 Production Development Schedule for Major Frame and Body Components

body components are then shipped from the frame and body component manufacturing plants to the vehicle assembly plants where initial volume production is started by the middle of July 1974. The first vehicle usually comes off the line 3 to 4 days after start of production. For purposes of uniformity and simplification, the full volume vehicle production start date has been placed at August 1, 1974.

5.3.2.2 Electronic Spark Advance and Electronic EGR Control

The production development schedule for the electronic engine controls system is shown in Figure 5-16. A lead time of 26-1/2 months is indicated. Since this is a functional system, portions of the product development cycle beginning with the start of prototype design precedes the production design approval milestone. Prototype design was started in March 1972 and is continuing at the present time. Prototype system testing, which was started in April 1972, is also continuing.

Production design was started in the middile of May 1972, and procurement of tooling and vendor equipment was initiated in August 1972, with completion scheduled for December 1972. Laboratory testing of production prototype samples for operating characteristics, such as durability, was planned to be initiated in December 1972 and will continue throughout most of 1973. This system will be phased into production, starting with a limited volume output scheduled for June 1973. These systems will be installed in 1974 Imperial models for observation of performance in customer use. Final release of EPA certification test cars is scheduled for September 1973, at which time durability and certification tests will be started. Full component production will start in July 1974, in preparation for production starting in August 1974.

5.3.2.3 Catalytic Converter System

The production development schedule for the catalytic converter system is shown in Figure 5-17. A 28-month lead time is indicated. This

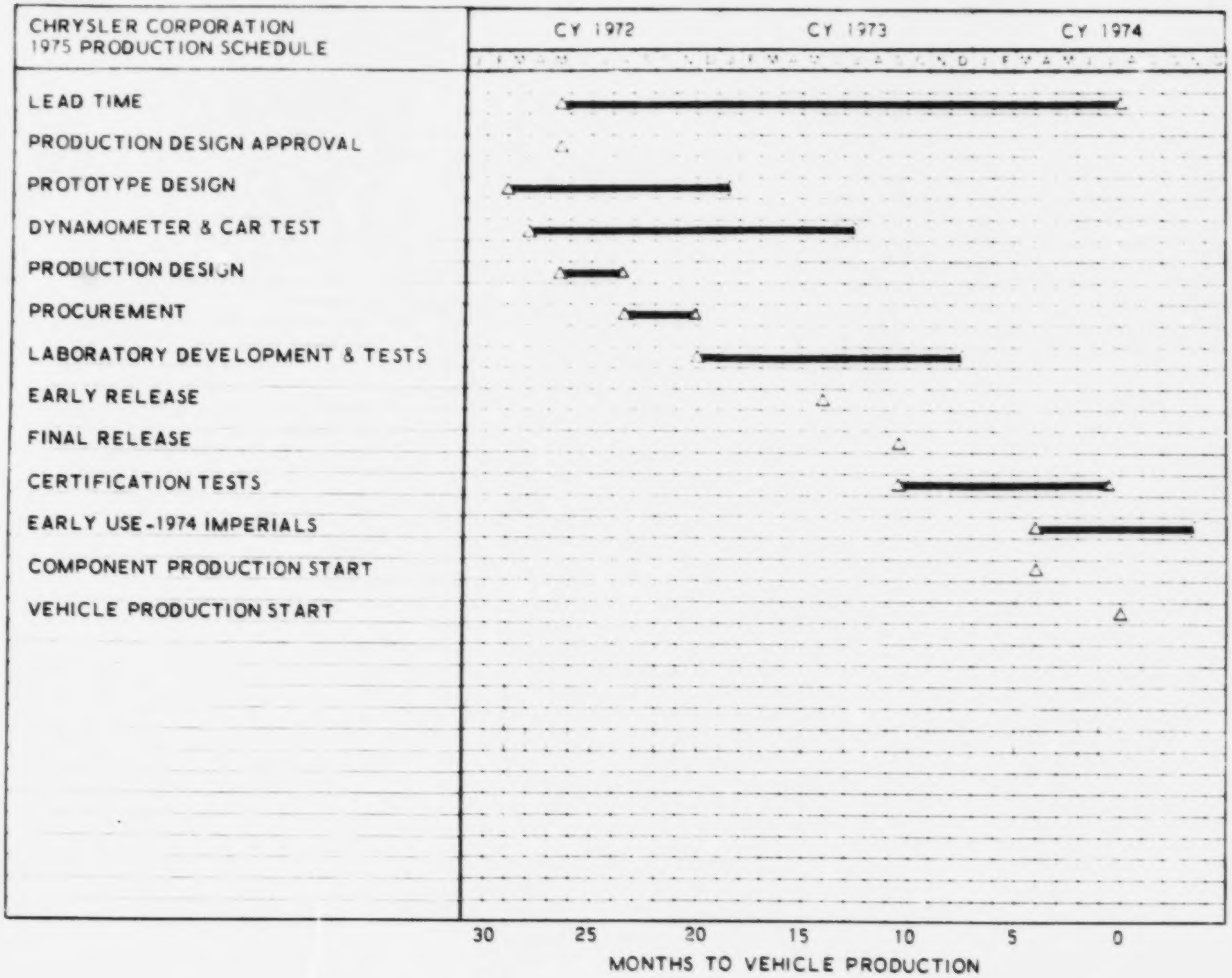


Figure 5-16. Chrysler 1975 Production Development Schedule for Electronic Spark Advance plus Electronic EGR Control

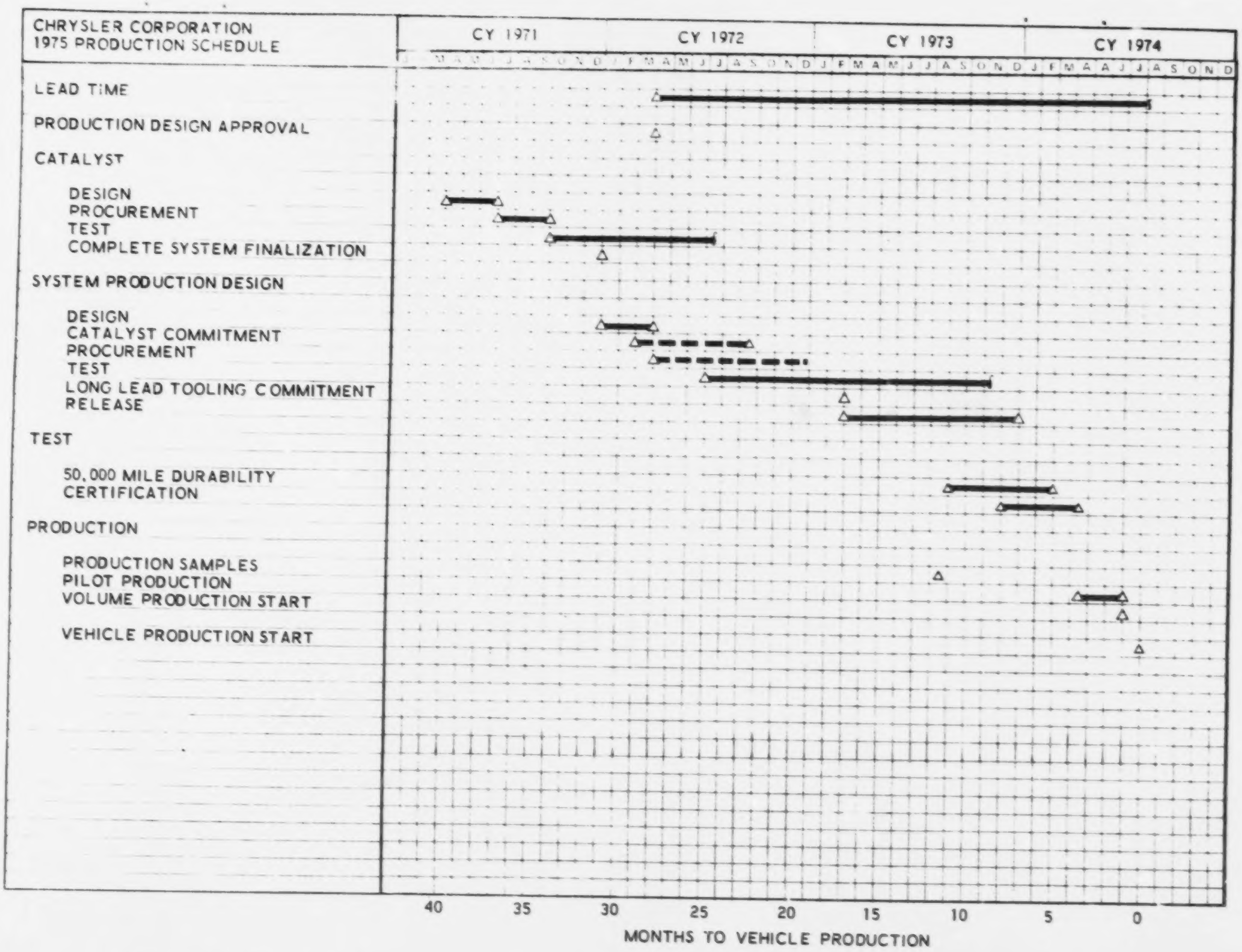


Figure 5-17. Chrysler 1975 Production Development Schedule for Catalytic Converter System

timing is based on Chrysler's submittal to the April 1972 Suspension Request Hearings.

Start of catalytic converter prototype design was initiated in April 1971; units for development test purposes were available by October 1971. Testing was initiated at this point and is still proceeding. Complete system finalization of the converter was scheduled for January 1972, but, as noted previously, has not yet been accomplished. Although the prototype system has not yet been demonstrated, Chrysler is proceeding with a preliminary production design which was established in April 1972. The commitment to a catalyst manufacturer was scheduled to take place in March 1972 but did not occur until September 1972.

The procurement of production prototype catalytic converters for test purposes was scheduled to start in April 1972 and end by July 1972, but the procurement has not yet been completed. For this reason, the testing of converters on automobiles which was scheduled to start in July 1972 is being performed with experimental systems and Chrysler is essentially still in the development phase. Long lead time tooling commitments are scheduled for March 1973 with progressive release over a period of 10 months ending in January 1974.

EPA durability certification tests are scheduled to start in September 1973 and end in March 1974. Emission vehicle certification testing starts in December 1973 and ends in April 1974. As the certification test cars are to be equipped with hardware similar in all material respects to production components, any delay in catalyst converter development and commitments will make it difficult for Chrysler to meet its scheduled test program.

Pilot production is scheduled to start in April 1974 and end in July 1974, at which time volume production of the catalytic converter system will start.

5.3.2.4 Carburetors

Figure 5-18 shows the production development schedule for the altitude-compensated, variable venturi carburetors. Chrysler has subcontracted the design, test, and production of these carburetors to Holley, Inc., Carburetor Division of Colt Industries. The total production lead time of 19 months is preceded by a considerable period of development by Holley, accompanied by Chrysler's usual coordination, followup, and evaluation activities.

The first carburetor samples cast from plaster molds were received from Holley in June 1972. This sample is a prototype made from soft tooling as opposed to the production-type sample which is die cast. After Chrysler's preliminary evaluation, from June 1972 through January 1973, Holley will be authorized to procure casting dies with receipt scheduled in January 1973. Development of the prototype carburetors by Holley continues from January 1973 to September 1973.

Initial die cast carburetors are produced at Holley, starting in January 1973 and continuing through December 1973. Chrysler authorizes Holley to procure the remaining production tooling in July 1973. Chrysler receives initial die cast production samples in September 1973. These samples are used in the durability and emission certification cars. Final development of the production-type carburetors takes place from September 1973 through June 1974; preliminary production approval by Chrysler is scheduled for February 1974.

Holley's final tooling checkout starts in October 1973. Final production samples are received by Chrysler in March 1974. The carburetor pilot run starts in February 1974 and ends in March 1974. Master production carburetors and specifications for different models needed for Chrysler's

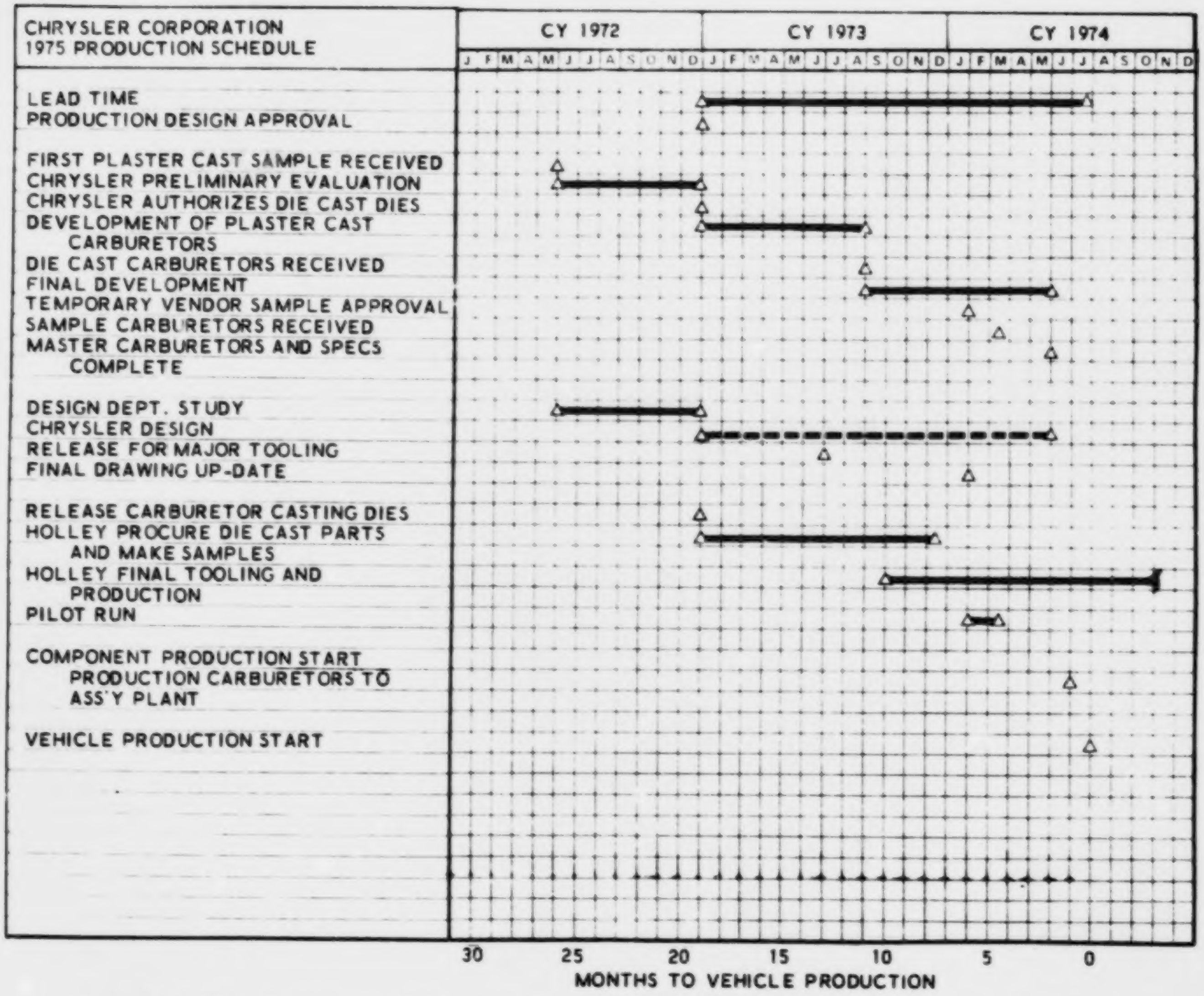


Figure 5-18. Chrysler 1975 Production Development Schedule for Carburetors

configuration control are completed by June 1974. Carburetors are delivered to the engine assembly plants by the end of June 1974. Full volume carburetor production starts in early July 1974.

5.3.3 Company/Vendor Schedule Consistency

A comparison of lead times obtained from Chrysler with lead times obtained from vendors for similar components was made to determine the degree of consistency relative to the components under discussion.

5.3.3.1 Major Frame and Body Components

Chrysler's data (Figure 5-15) indicate a lead time of 22 months for major frame and body components. These were compared with data from Sections 7.1 and 7.2. However, because Chrysler's schedule did not delineate differences in lead time between body and frame components, it was not possible to compare these on an individual basis. A period of 22 months is indicated for body stampings. Lead time for frames is 15-1/2 months if existing facilities and press lines could be used and 35 months if new facilities and processes were required. Thus, assuming that no new facilities and press lines are required, it can be stated that the consistency shown is good for the combination of body and frame components.

An additional comparison may be made using Chrysler's 1973 model year master timing schedule (Ref. 5-3). This schedule basically represents a normal model changeover. The lead time required for the frame and body components, based on data for the highest volume production model made by Chrysler, is shown in Figure 5-19. The total lead time requirement is 26 months as compared with the 22 months allowed for 1975 production. This would suggest that Chrysler has compressed its normal frame and body component lead time for 1975. This compression may be the result of delays in styling approval due to unknowns that exist relative to modifications required by the catalytic converter system. Because these unknowns still exist to some degree, Chrysler is proceeding with frame and body design on a relatively high risk basis using an assumed design for the catalyst container configuration and for associated systems that interface with the frame and body.

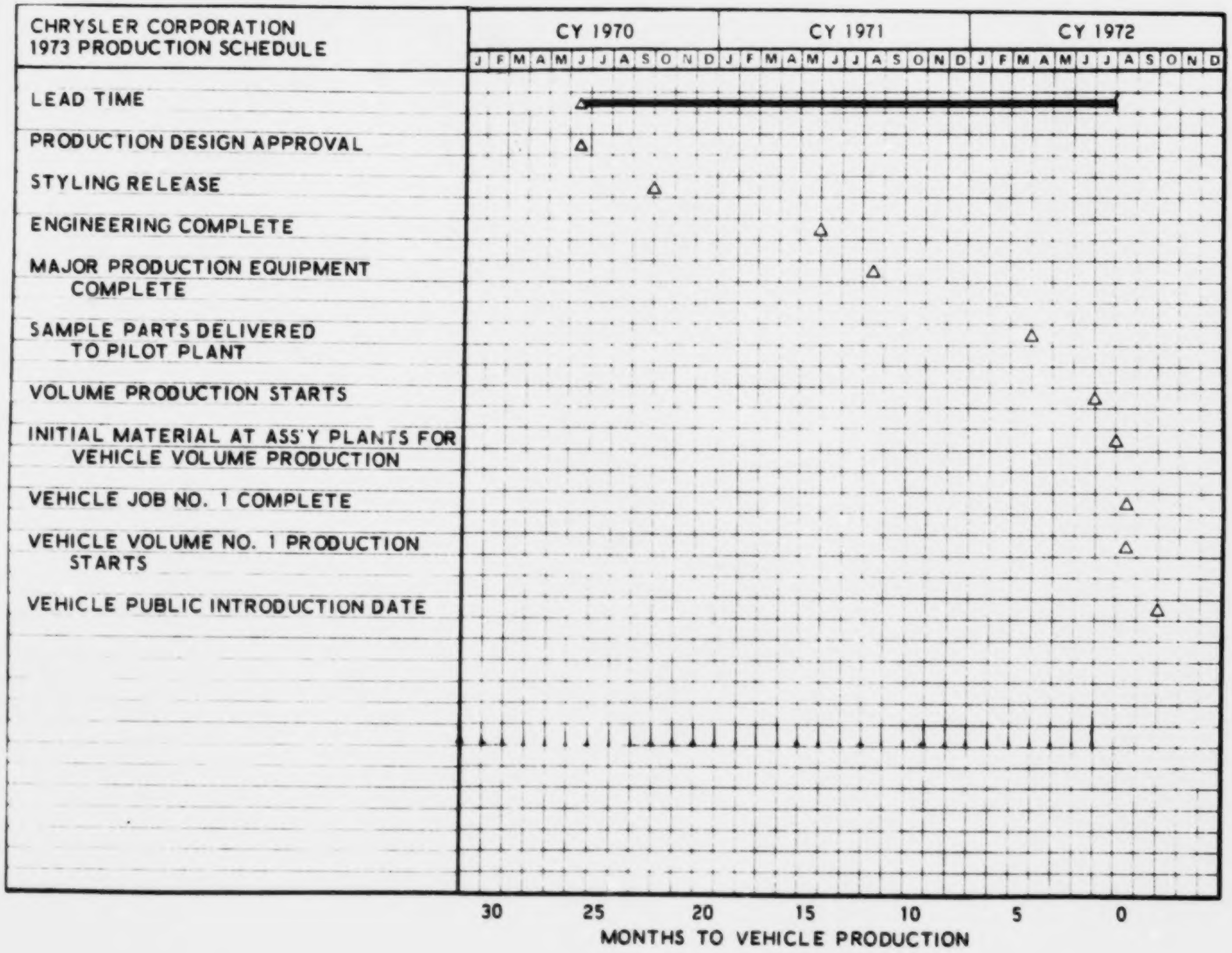


Figure 5-19. Chrysler 1973 Production Development Schedule for Major "B" Body Sheet Metal

5.3.3.2 Electronic Spark Advance and Electronic EGR Control

No vendor data were obtained to test the consistency of Chrysler's lead time.

5.3.3.3 Catalytic Converter System

5.3.3.3.1 Catalyst Substrate Manufacture

In order to meet the certification test schedules, catalytic converters similar in all material respects to production units are required before September 1973 for initial testing and installation into the durability test cars. At this time it is uncertain that production-prototype hardware will be available to meet this schedule.

Information from the substrate manufacturers is insufficient to place an exact date on the availability of production samples. However, some data on the timing for volume production is available. W. R. Grace stated in August 1972 that it requires a lead time of 22 months after go-ahead (customer commitment). It has not yet received a commitment from Chrysler. If Chrysler commits by November 1972, the Grace lead time would result in the start of volume production by August 1974. This schedule is not likely to allow sufficient time for fabrication and assembly of catalytic converters for the start of 1975 model production.

5.3.3.3.2 Catalyst Manufacture

In August 1972, UOP stated that it could set up volume catalyzing operations by April 1974 if it was given a commitment for technology development by September 1972 and a commitment for construction by the end of December 1972. If UOP itself were to obtain the substrates, a Chrysler commitment by January 1, 1973 with orders placed by May 1973 would be required. UOP must know the exact substrate configuration by July 1973 to design the tooling and production equipment and must have substrate volume delivery early in 1974. Matthey Bishop provided similar lead times to meet an April 1974 volume production date.

5.3.3.3.3 Catalyst Canister Manufacture

Data obtained from Hayes-Albion indicate that canister production samples require a lead time of 6 months and that a lead time of 10 to 11 months is required for volume canister production. If Chrysler will take care of the containers needed for EPA certification and pilot cars using soft tooling, these lead times would require that a purchase order for high volume production be placed with a subcontractor by approximately August 1973. Otherwise, a vendor purchase order would be required by January 1973 to allow sufficient time for pretest and assembly into these cars prior to start of EPA certification testing in September 1973.

5.3.3.4 Carburetors

A carburetor schedule comparison showed a 19-month lead time specified by Chrysler and an 18-month lead time noted in Section 7.4. In general, the activity milestones seem to agree. For example, Chrysler's Preliminary Evaluation of the First Plaster Cast Carburetor from June 1972 through December 1972 is in reasonably good agreement with the Customer Calibration with Initial Prototype from September 1972 to January 1973 given in Section 7.4. Similarly, Chrysler's Development of Plaster Cast Carburetors from January 1973 through September 1973 also is in reasonably good agreement with the Customer Calibration with Early Prototype from February 1973 through July 1973.

5.3.4 Current and Pending Contractual Agreements

5.3.4.1 Frame and Body

For major frame and body components, Chrysler is following its normal procedures in using its usual vendors. No problems relative to commitments and agreements are foreseen.

5.3.4.2 Electronic Spark Advance and Electronic EGR Control

For electronic spark advance and electronic EGR controls, no problems relative to contractual agreements are foreseen.

5.3.4.3 Catalytic Converter System

Major contractual problems that relate to the catalytic converter system are discussed below.

5.3.4.3.1 Substrates

Chrysler has discussed possible manufacturing effort with several potential substrate suppliers including the American Lava Corporation, Corning Glass Works, AC Spark Plug, Ford, and Grace. It feels that American Lava cannot supply enough substrates and that Corning is also doubtful as a potential high volume supplier. These sources of supply must immediately demonstrate their ability to convert their technology into high volume production. Chrysler has not entered into any contractual agreements with any of the above companies.

5.3.4.3.2 Catalyst Manufacture

Chrysler signed a contractual agreement with UOP in September 1972 (Ref. 5-2) for the catalyst and wash coat operations and is considering Matthey Bishop as another potential catalyst source. The agreement with UOP is for engineering and development for catalyzing processes and Chrysler must commit to a plant construction contract by the end of December 1972. Contractual agreements with Matthey Bishop, however, are presently not known. These catalyst manufacturers would receive substrates supplied by Chrysler or by Chrysler vendors.

In September 1972, Chrysler also entered into a contract with the Ore and Chemical Corporation for the delivery of 100,000 troy ounces of palladium from the Soviet Union (Ref. 5-2). Since Chrysler's catalyst will probably be a mixture of platinum as well as palladium, a commitment for procurement of platinum is still required. The present status on platinum procurement is not known. It is reported (Ref. 5-2) that 100,000 troy ounces of palladium is insufficient to supply Chrysler's requirements for 1975 cars and that the source of the additional palladium needed has not been identified.

5.3.4.3.3 Catalyst Canister Manufacture

It appears that Chrysler intends to manufacture most of its catalyst canisters in-house. Arvin Industries, Inc., Walker Manufacturing Co., and Hayes-Albion Corp. are potential vendors for manufacturing part of Chrysler's canister requirements. At this time Chrysler has made no commitments to any of these potential sources.

5.3.4.4 Carburetors

Chrysler has a contract with Holley, Inc. and no problems are foreseen.

5.4 AMERICAN MOTORS CORPORATION

5.4.1 Overall Schedule, 1975/76

5.4.1.1 Production Schedules

American Motors has been working to schedules based on achievement of full production of 1975 model year automobiles by August 1, 1974. The schedules are influenced by American Motors relatively small size, which requires that it rely to a large degree on component and equipment technology developed outside the company. Its normal schedule is largely based on a 58-hour work week for one shift.

American Motors production program timing schedule detailing lead time requirements for body and engine modifications needed to meet 1975 emission control objectives is shown in Figure 5-20. As differentiated from previous production years, the 1975 model year cars will require changes to the engine cylinder head, engine intake and exhaust manifolds, and body floor pans, as well as the addition of a catalytic converter.

Key points to be noted are:

a. Preliminary release of all 1975 engine changes is planned for November 1, 1972.

b. Detail drawings on critical long lead items (e.g., the cylinder head design change) would be released on March 1, 1973.

c. EPA Certification Tests would begin on November 1, 1973.

d. Tool construction would be completed on March 1, 1974.

e. 1975 engines would be installed in sales prototype vehicles (first build from production-tool parts) beginning on March 1, 1974.

f. Job No. 1 (first car on limited production run) is planned for May 1, 1974.

g. Volume Job No. 1 (first car on full production run) is planned for August 1, 1974.

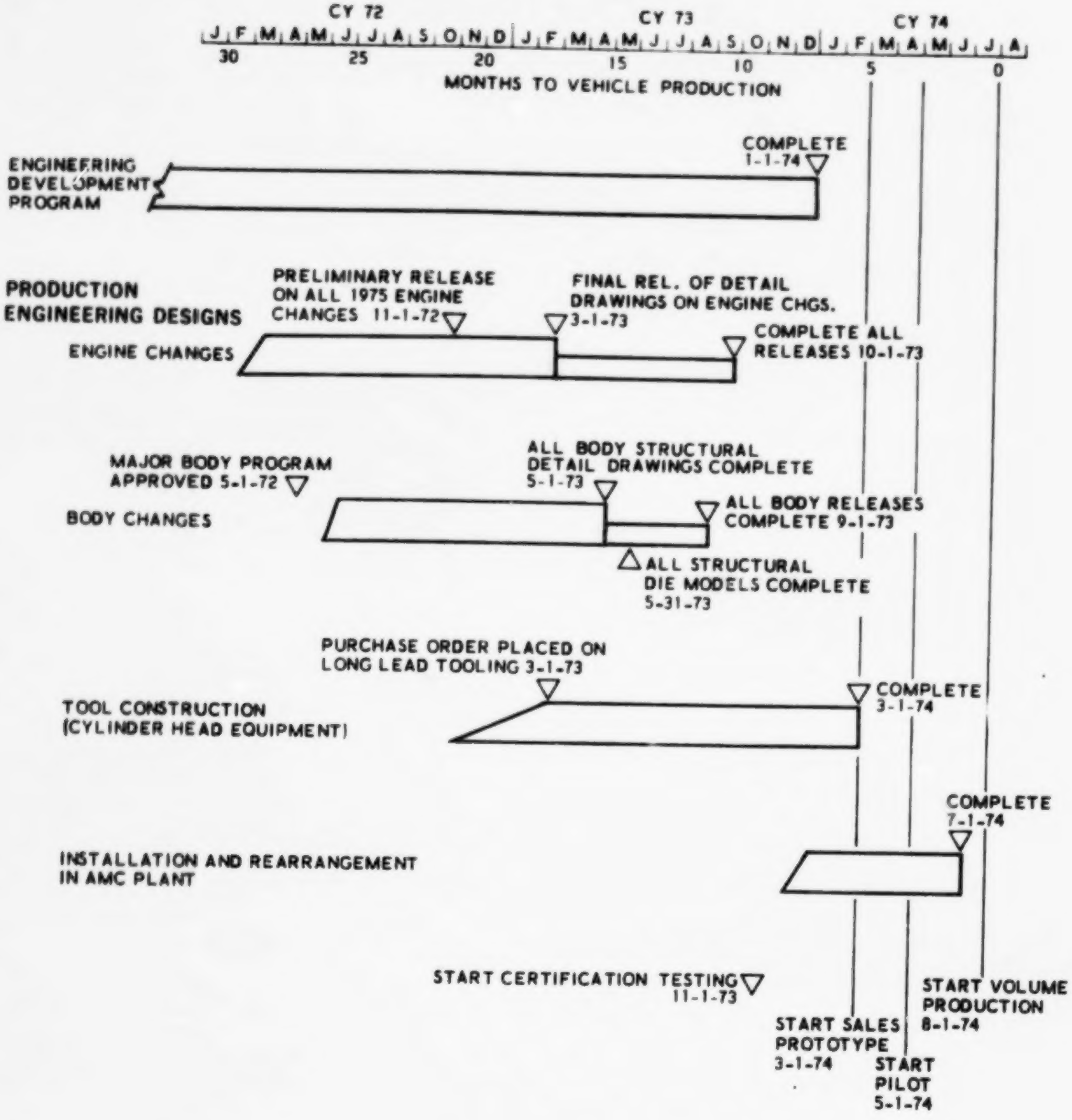


Figure 5-20. American Motors 1975 Emission Control Program Timing Study

Shutdown for phaseout of the previous model year and changeover to the next model year occurs from July 15 to August 1.

From product inception through drawing release to product production, design changes are handled within engineering and are required to fall inside the management-approved overall vehicle design parameters set up for the model year in question. After formal engineering drawing release (which initiates production tooling orders, facility planning operations, and finalization of vehicle cost quantities), changes are controlled by the ECR (Engineering Change Request) procedure. The ECR procedure involves manufacturing, manufacturing engineering, product planning, purchasing, and engineering. Concurrence and signoff from all of these groups is required to implement the changes in question. Drawing release to manufacturing must be such that 1975 model year production parts are available on March 1, 1974 in readiness for the start of sales prototype vehicle assembly. Consequently, die models for major body components must be completed on May 31, 1973 and chassis drawings must be released by December 1, 1973.

Emission control system packaging concepts, plans, and scheduling for the 1976 model year are currently being prepared, but no specific information concerning manufacturing development schedules for these systems is available at this time. According to American Motors, the type of schedule discussed for the 1975 model year is not applicable for the 1976 model year.

5.4.1.2 Major Impact Factors

Prior to emission control and safety regulations, American Motors did not commit designs to production until development was completed. However, like other automobile manufacturers, it is now proceeding with production development on a schedule which accommodates a catalytic converter design that is still under development.

Incorporation of the emission control system requires many design changes to different areas of the automobile that are impacted by the control system components. These design and subsequent manufacturing changes are major factors in establishing the final lead time requirement for 1975 model year production development. The major changes anticipated in 1975 American Motors cars involve the following components and subsystems:

a. A new cylinder head for the V-8 engine to reduce exhaust valve leakage, improve cooling capacity, and improve casting techniques. Four different design concepts have been reviewed. The design objective is to reduce exhaust valve leakage so that the 50,000-mile durability requirement for emission control may be met. In order to improve cooling, the two-piece core cylinder head casting will be changed to a one-piece core. The long lead time items related to the manufacture of the new cylinder head are new transfer lines and assembly equipment. At this time, American Motors has made about 50 prototype cylinder heads for testing, using "soft tooling."

b. Body and structural changes to accommodate the catalytic converter. A study has been under way to consider floor pan changes that are necessary to accommodate a catalytic converter in the 1975 product line. A major problem in accommodating the converter is American Motors unibody structure which is less flexible to changes than the conventional frame and body design. To make room for the catalytic converter, a significant modification of the design is required in order to maintain structural integrity. The degree of change is dependent on whether a small monolithic converter can be used or whether the larger pellet-type converter will be required. The type of tooling and equipment used for the structural changes consist of dies for rigid body parts and conventional assembly equipment to install the purchased converter.

Tooling and equipment (involving new machines, welders, and assembly transfer stations) would have a major schedule impact if American Motors had to revise its engine installation process. Presently, the engine is installed from below after the body is completely assembled. The engine mount cross-member is attached to the engine prior to installation and is used for the front suspension system. The carburetor, distributor, EGR system, valves, air pump, and controls are installed on the engine by manual means. If a catalytic converter system of another design required that the engine be installed from above, major changes in design and assembly would be necessary.

Experimental prototype testing is currently being conducted on the emission control system mounted in test-bed vehicles. To date, American Motors has not successfully demonstrated that the system can meet Federal emission standards for 50,000 miles. Catalytic converter configuration changes emanating from this program may have a serious impact on the design of the 1975 model year automobile as well as on the design of equipment and tooling. Also, unless successful results are forthcoming, other prototype tests (involving the use of 1975 model year hardware throughout the car) may be rendered invalid.

5.4.1.3 Critical Lead Time Items

The critical path lies with vendor lead time requirements for catalytic converter production. (However, at the time of the EPA Suspension Request Hearings in April 1972, the critical path was associated with the requirement for new cylinder heads; this is still considered to be a serious timing factor.) The timing schedule for the 1975 catalytic converter and associated body changes is shown in Figure 5-21. This schedule for the converter basically reflects the need for the supplier to develop completely new facilities for the volume manufacture of catalytic converters required for 1975 automobile production.

The anticipated changes required for or related to American Motors 1975 emission control system, ranked in terms of critical lead time, are as follows:

Catalytic converter / New cylinder head
for the V-8 engine

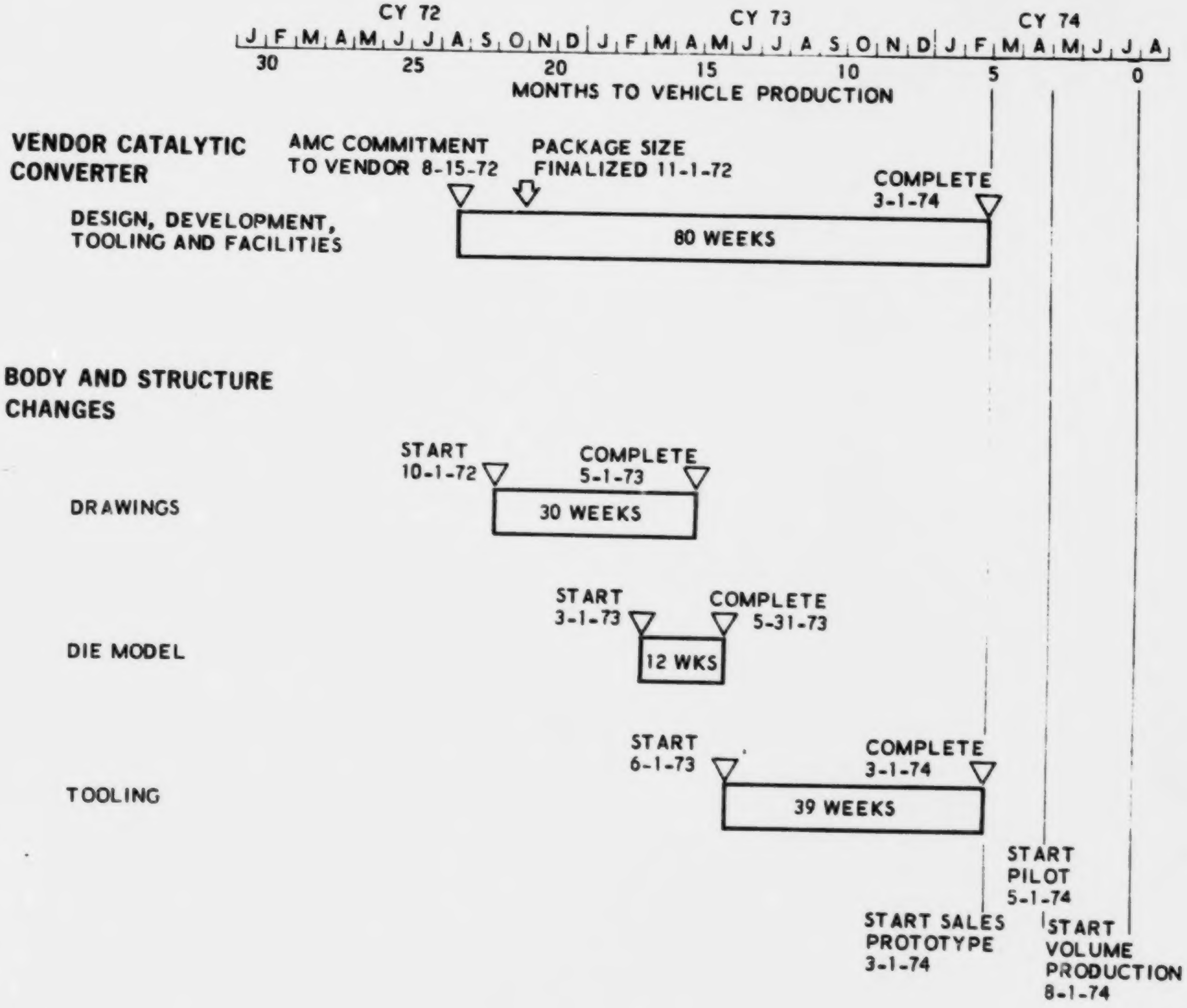


Figure 5-21. American Motors 1975 Catalytic Converter and Associated Body Changes Time Study

Body and structure changes to accommodate catalytic converter

New carburetor

New intake manifold

Breakerless ignition system

American Motors is carrying two different catalytic converter designs at this time. Different converters may be used on different cars. The incorporation of oxidizing catalysts also involves the installation of an air pump. It is understood that General Motors will supply the air pump, but the American Motors source of supply for catalytic converters has not been revealed at this time; a verbal commitment to one potential supplier was made in August 1972 (see Section 5.4.4).

Because of its small volume production, American Motors is more dependent on outside suppliers than the big three automobile manufacturers. For example, the V-8 engine cylinder block is cast by General Motors (American Motors 6-cyclinder engine is cast in-house by a subsidiary).

With regard to body changes, the major sheet metal pieces and the instrument panel are the long lead time items. The critical items on sheet metal parts are the dies.

The new carburetor, ignition system, and EGR valves are purchased items and are procured from the most economical source. Tooling and equipment required for these parts are minimal since they are installed at American Motors by hand labor.

The changes to the intake manifold are required to provide quick warmup capability. Plans are to purchase the castings outside with the machining done by American Motors. This involves modifications to machining and transfer equipment, or completely new equipment, depending on the finalized design. American Motors assumes that vendor capability and facilities will be available for all of the purchased components.

5.4.1.4 Prototype Test Programs

American Motors is somewhat informal in dealing with catalytic converter suppliers; detailed specifications for catalytic converter performance are not delineated.

American Motors is presently testing three cars with prototype catalytic converters. It considers this sample size too small to be representative, but felt compelled to make an early commitment to a specific test design. Test results have not proven to be satisfactory to date.

In order to be reasonably sure of meeting emission standards with production cars, American Motors believes a 25% performance margin is required between prototype and production vehicles.

According to American Motors, the 50,000-mile EPA certification test requires a period of 5 months, based on running cars 6 days per week for 24 hours per day. If the remaining time is short, cars will be run 7 days per week.

5.4.1.5 Schedule Compression

The timing schedules that were discussed previously (Figures 5-20 and 5-21) represent normal program timing. Acceleration of these schedules is dependent upon the successful early completion of engineering development, as well as the ready availability of vendor equipment and tooling facilities at the time purchase orders are placed.

Tool schedule compression is related to the availability of Keller machines. These machines are used to make die models; relatively few are available. An additional tooling consideration has been the procurement of induction hardening equipment for valve seats on cylinder blocks. This equipment is required by all automobile manufacturers because of the planned operation of engines with unleaded gas. At present, only one company (Tocco Division of Park-Ohio Industries, Inc.) manufacturers this equipment. No criticality in availability of this equipment has been found however.

According to American Motors, the relationship between schedule compression and product cost is affected by investments (facilities and tools) as well as piece cost based on labor utilization. In regard to labor costs, it is normal practice to work single-shift, 58-hour weeks with full utilization of manpower during that time. Some tooling sources will also work two 58-hour shifts at the same hourly rate. The maximum schedule compression (3 shifts: 24 hours per day, 7 days per week) results in costs of 1-1/2 to 2 times the costs accruing from the 58-hour rate. However, spending additional funds normally has little effect on compressing program timing. Hence, it is standard practice to pay compression costs only on those items which are on the critical path if this action is needed in order to keep the program on schedule.

In regard to the influence of investment costs, the product cost should not change if the tooling is identical. However, if the schedule compression results in the use of less automation, the piece cost will go up. In addition, if the tooling is not finished and special fabrication methods are required to meet production, the piece cost is adversely affected.

5.4.2 Major Elements in Schedule

The process American Motors uses in developing a new vehicle is described in this section. The product activity flow network is shown in Figure 5-22. Milestone dates related to this network were considered proprietary and were not furnished. However, it may be stated that the span of time between the product planning (concept) stage and the presentation for approval can vary from a maximum of 2 to 3 years for an all-new vehicle to a minimum of about 4 months for a minor change. The span of time between approval and volume production also varies with the degree of complexity.

In general, body changes require a 3-year cycle and engine changes require 5-year cycles; year after year the same items are critical for normal automobile model changes. The process steps involved in a representative American Motors car development program are discussed below.

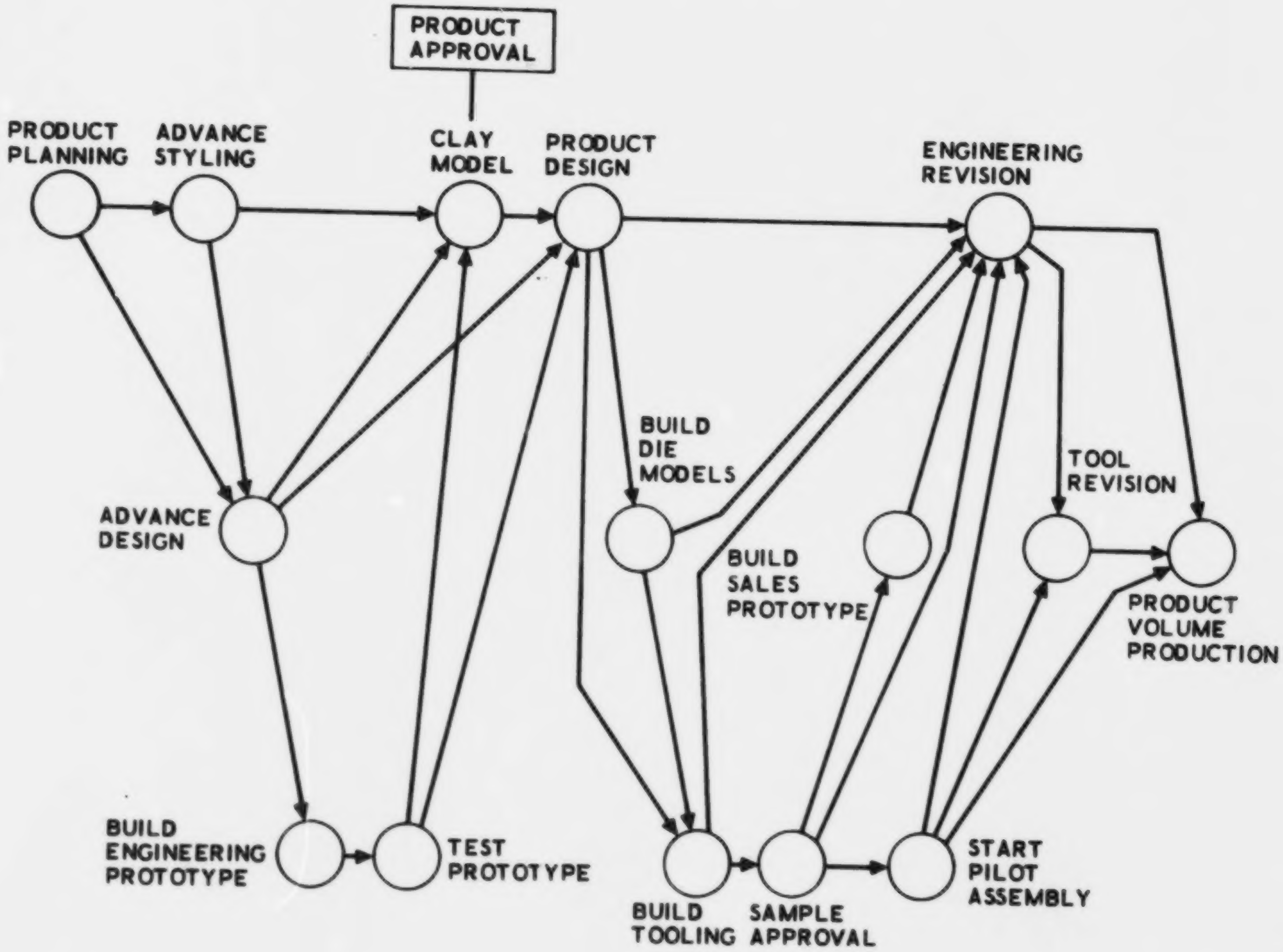

PRODUCT APPROVAL
PRODUCT PLANNING
ADVANCE STYLING
CLAY MODEL
PRODUCT DESIGN
ENGINEERING REVISION
ADVANCE DESIGN
BUILD DIE MODELS
TOOL REVISION
BUILD SALES PROTOTYPE
PRODUCT VOLUME PRODUCTION
BUILD ENGINEERING PROTOTYPE
TEST PROTOTYPE
BUILD TOOLING
SAMPLE APPROVAL
START PILOT ASSEMBLY

Figure 5-22. American Motors Summary Network of Product Creation

5.4.2.1 Part I - Concept to Approval

5.4.2.1.1 Concept

Product Planning develops the basic objectives. These include the theme or image, estimated piece cost, required investment, and the overall program timing. The theme is reviewed with the Marketing Office to determine the marketability of the vehicle. The information package is then transmitted to the Advanced Styling and Engineering Offices.

5.4.2.1.2 Development

Advanced Styling develops the theme in clay. Styling works in conjunction with Engineering to insure: (a) manufacturing feasibility, (b) that the driveline can be accommodated, (c) that mannikin positioning is within basic objectives, and (d) that the structural integrity of the proposed body is retained. The Safety Office reviews the clay to ensure that all current statutes can be met, and that considerations related to proposed legislation are incorporated in the theme.

Product Cost Control reviews the concept continually to ensure that the cost (piece and investment) objectives will be met. With management approval, an engineering prototype is then built from soft tooling using advanced drawings to evaluate the following:

Spatial characteristics
Component interrelationships
Manufacturing techniques
Assembly processes

During the entire advance development stage there are periodic review meetings with all levels of corporate management.

5.4.2.1.3 Presentation

The entire program is pulled together for a presentation to corporate management for car program approval. At this presentation, costs, marketing strategy, manufacturing feasibility, and product content are reviewed and evaluated and authorization to proceed with manufacturing development is either given or denied.

5.4.2.2 Part II - Approval to Volume Production

When a program has been approved, the following steps leading to volume production are taken.

Styling transmits final surface information to Engineering.
Engineering develops production drawings for the body and chassis.
Die models are built.
Purchase orders are placed.
Tools are built.
Samples are approved.
Prototype vehicles are built and reviewed.
Pilot assembly starts.
Volume production is achieved.

After American Motors management approval of a program, authority to buy is initiated through issuance of a Manufacturing Release Form based upon an Engineering Release with the appropriate blueprint package. (Production buying is centralized in Detroit.) Buyers send blueprint packages and appropriate instructions to vendors and normally award business to the lowest combined tooling and piece cost bidder. On components or systems requiring extensive vendor design assistance, an early sourcing decision may be required. In such instances, special meetings are held with personnel from the major in-house activities concerned to evaluate the alternate sources.

5.4.3 Company/Vendor Schedule Consistency

By using Figures 5-20 and 5-21 as a basis of reference, production lead times cited by American Motors can be compared to specific examples of production development lead time taken from Section 6 for substrate and catalyst manufacture and from Sections 7 and 8 for component and equipment manufacture.

Twenty months are required for fabrication and checkout of 14 sections of an automatic transfer line for cylinder head machining (Section 8. 1) This figure corresponds very well with the lead time of 21 months indicated in Figure 5-20 for the milestone identified as Preliminary Release On All 1975 Engine Changes. (Note: it is not known how many sections are planned for American Motors cylinder head production operation.)

Using receipt of order as the point of reference for initiating work by a vendor, body stampings require a lead time of 22 months (Section 7. 1). This can be compared in a general sense with American Motors 26-month lead time for its Body Change Program (Figure 5-20). It would seem reasonable to assume that the 4-month differential period is required by American Motors to complete drawings defining body contours.

In regard to structural detail drawings, Figure 5-20 indicates a lead time requirement of 15 months. This compares quite well with data presented in Section 7. 2 indicating a lead time requirement of 15-1/2 months for body frames.

Figure 5-21 indicates a lead time of 23-1/2 months for the milestone identifying the American Motors commitment to substrate and catalyst manufacturers. This time compares favorably with lead times cited by two firms contacted by American Motors: Matthey Bishop, Inc. specified a 22-month lead time for Start of Building Design (Section 6. 8), and Englehard Minerals and Chemical Corporation specified a 23-1/2 month lead time for Release of Work on Plant No. 2 (Section 6. 4).

In summary, it appears that the American Motors production development schedules show reasonable consistency with the schedules of its potential suppliers and with lead times specified for the production development of various atuomotive assembly equipment and tooling.

5.4.4 Current and Pending Contractual Agreements

As noted previously, the relatively small size of American Motors requires that it rely to a large degree on component and equipment technology developed outside the company. Most procurements are made on the basis of purchase orders; cancellation contract agreements are generally in effect whenever significant capital investments on the part of the supplier are involved.

A verbal commitment to one catalytic converter supplier for a completely packaged device was made in August 1972. Neither the details of the arrangements nor the name of the supplier are available at this time. However, it is known that American Motors has contacted Englehard, AC Spark Plug, and Matthey Bishop as potential suppliers.

It is anticipated that the verbal agreement will be bolstered by a formal contract after design and delivery details are reviewed and agreed upon. Talks are continuing with potential suppliers and more than one contract may be released by American Motors.

From the timing chart shown in Figure 5-20, purchase orders were scheduled to be released in November 1972 for V-8 engine cylinder block castings from General Motors and for new machine, transfer, and assembly equipment for fabrication of new cylinder heads (possibly to Joseph Lamb Company which supplies the majority of this equipment). Subsequently, release should be given for purchase of carburetors (likely to Holley, Inc.). Purchase orders are also pending for other elements in the emission control system such as the ignition system and EGR valves.

REFERENCES

5-1. Ford, May 1971 letter to Ruckelshaus on program timing

5-2. S. Lipsky, "Chrysler to Buy Palladium from Soviet for Possible Use in Anti-Pollution Devices," Wall Street Journal, September 21, 1972.

5-3. Chrysler Corporation, "Corporate Master Timing Schedule for 1973 Model Year," January 24, 1972.

SECTION 6

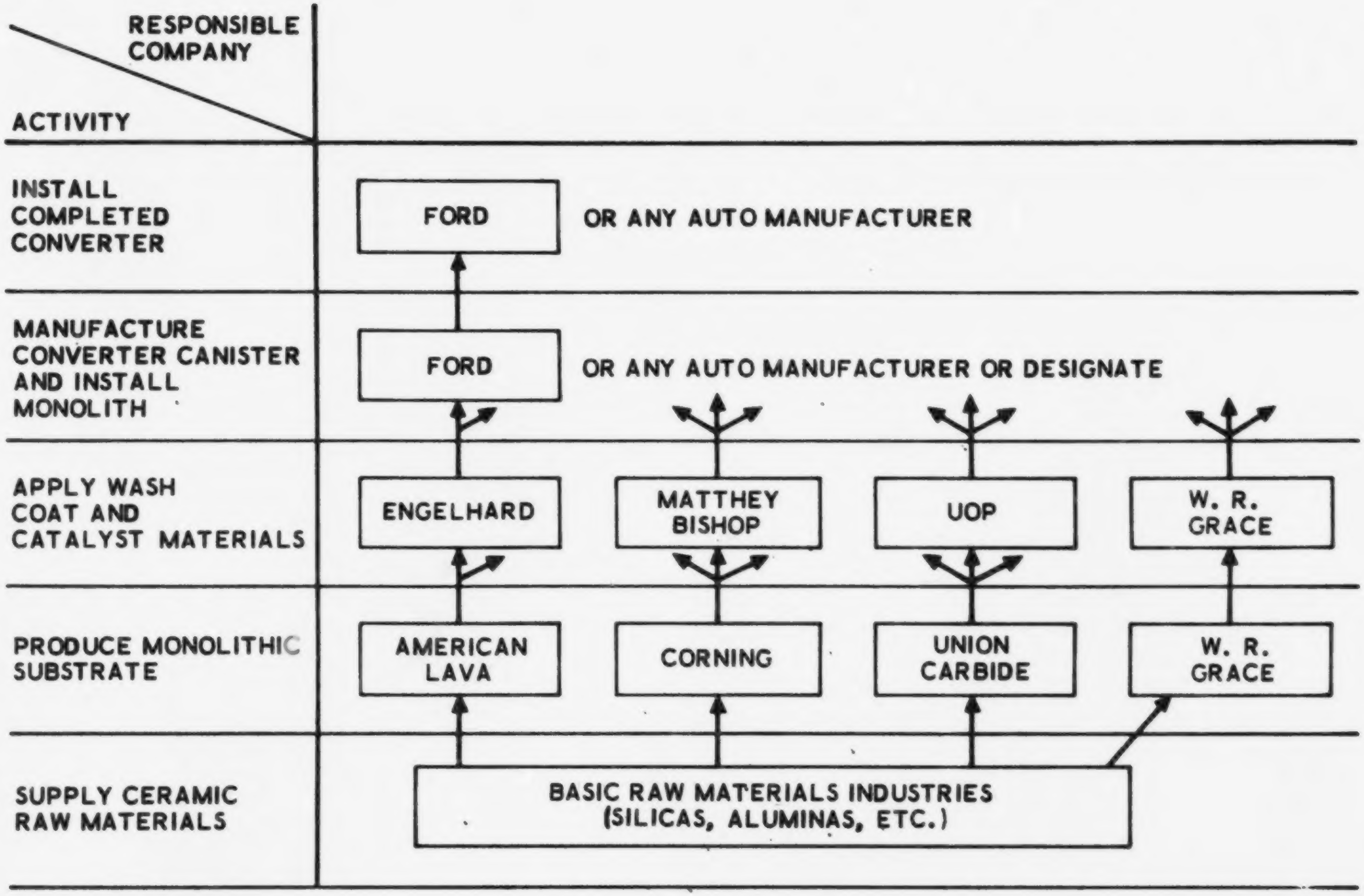
LEAD TIME SCHEDULES FOR CATALYST AND SUBSTRATE MANUFACTURERS

The following information concerning catalyst and substrate product description and production lead time schedule status and projections was obtained during detailed discussions held with the noted manufacturers in the August through October 1972 time period. (The list of companies visited and dates of discussions are given in Appendix A.) Particular emphasis was directed to the production lead time schedule status of substrate and catalyst manufacturers because the catalytic converter is considered by all automobile manufacturers to be the critical lead time component for the 1975/76 model year automobile.

6.1 SUMMARY DISCUSSION

6.1.1 Converter/Catalyst/Substrate Relationships

The production of catalytic converters (oxidation or reduction) for use in automotive emission control systems requires a high degree of interactive planning and coordination between potential supplier and user organizations, as shown in Figures 6-1 and 6-2 for monolithic and pelletized catalytic converters, respectively. At one extreme, a different company (or several companies) could be involved in each phase of the overall catalytic converter fabrication and installation for a given automotive manufacturer. In other cases, a single company may be involved in two or more activity phases, e.g., W. R. Grace and Company could both produce the substrate and apply the wash coat and catalyst material(s) to the substrate. At the other extreme, a given automobile manufacturer, e.g., General Motors Corporation, could procure basic raw materials and perform all manufacturing and installation phases in-house. This latter case may be difficult to achieve during the initial introduction period of the catalytic converter.



RESPONSIBLE COMPANY
ACTIVITY
INSTALL COMPLETED CONVERTER
MANUFACTURE CONVERTER CANISTER AND INSTALL MONOLITH
APPLY WASH COAT AND CATALYST MATERIALS
PRODUCE MONOLITHIC SUBSTRATE
SUPPLY CERAMIC RAW MATERIALS
FORD
OR ANY AUTO MANUFACTURER
FORD
OR ANY AUTO MANUFACTURER OR DESIGNATE
ENGELHARD
MATTHEY BISHOP
UOP
W. R. GRACE
AMERICAN LAVA
CORNING
UNION CARBIDE
W. R. GRACE
BASIC RAW MATERIALS INDUSTRIES (SILICAS, ALUMINAS, ETC.)

Figure 6-1. Monolithic Catalytic Converters, Typical Flow of Responsibilities (Examples Only)

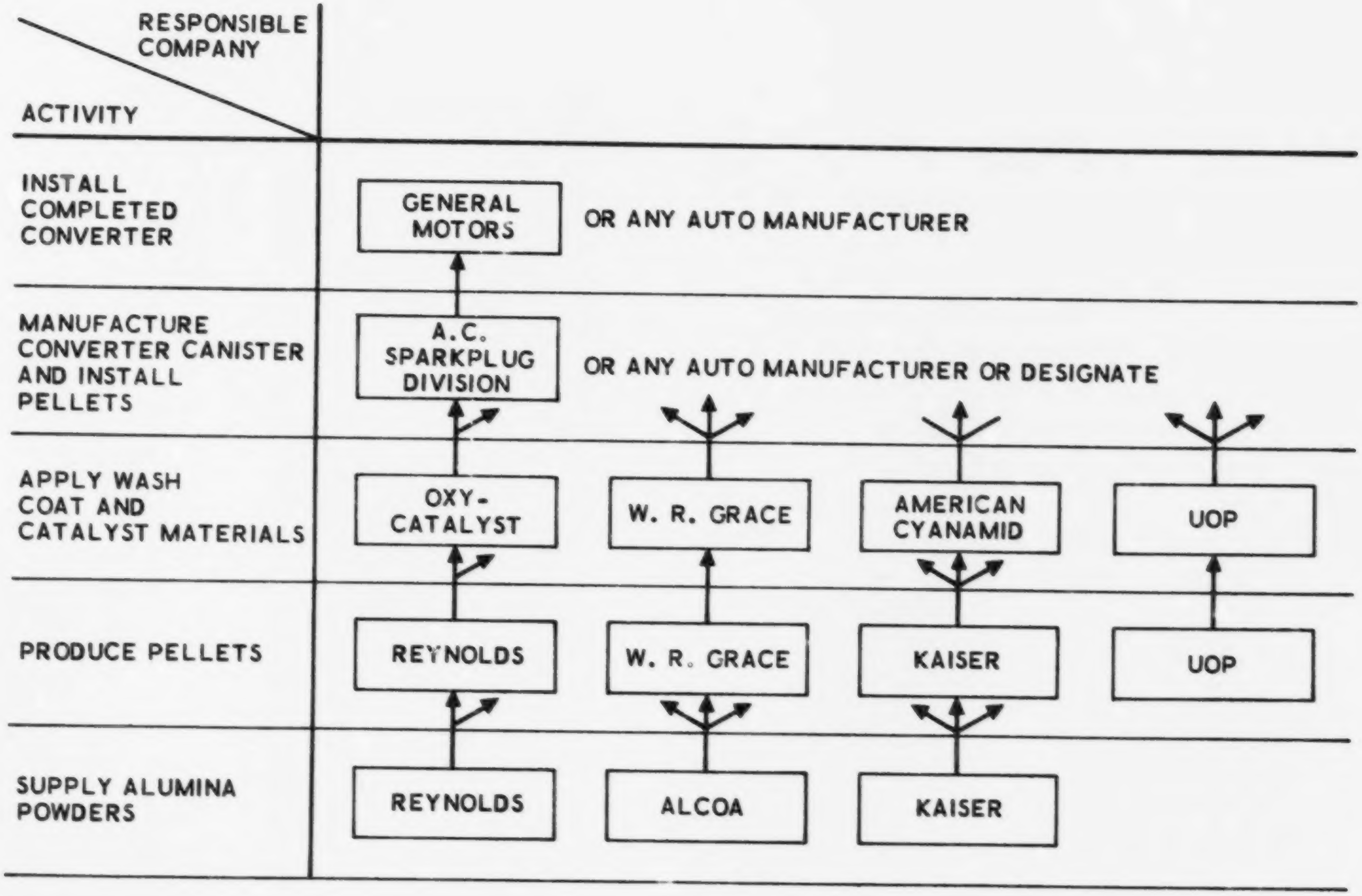

RESPONSIBLE COMPANY
ACTIVITY
INSTALL COMPLETED CONVERTER
GENERAL MOTORS
OR ANY AUTO MANUFACTURER
MANUFACTURE CONVERTER CANISTER AND INSTALL PELLETS
A.C. SPARKPLUG DIVISION
OR ANY AUTO MANUFACTURER OR DESIGNATE
APPLY WASH COAT AND CATALYST MATERIALS
OXY-CATALYST
W. R. GRACE
AMERICAN CYANAMID
UOP
PRODUCE PELLETS
REYNOLDS
W. R. GRACE
KAISER
UOP
SUPPLY ALUMINA POWDERS
REYNOLDS
ALCOA
KAISER

Figure 6-2. Pelletized Catalytic Converters, Typical Flow of Responsibilities (Examples Only)

6.1.2 Typical Catalyst and Substrate Products Available

The spectrum of potential catalyst and substrate suppliers and their principal products are summarized in Tables 6-1 and 6-2. The product mix depicted further illustrates the wide range of choices and/or supply options available to the automobile manufacturers during their current catalyst selection activities and catalyst supply negotiations. In the case of oxidation catalysts, the full range of product options is offered (noble metal, base metal, promoted base metal, pellets, monoliths), with multiple sources of supply in each case. In the case of reduction (NO_x) catalysts, multiple sources of pellet or monolithic ceramic catalysts are potentially available. Some companies are also considering offering all-metal monolith units (i.e. rolled wire mesh).

6.1.3 Production Lead Time Schedule Requirements

6.1.3.1 Catalyst Manufacturer Schedules

A summary of the production lead time schedules currently proposed by representative catalyst manufacturers is shown in Figure 6-3. As can be seen, all schedules are structured to start full production for 1975 model year requirements in the April to July 1974 time period. Oxidation catalyst units needed for pre-production stockpiling and/or vehicle emission certification testing, etc. would be provided from units produced during the plant startup and shakedown period (January to July 1974) or from separate pilot and batch processing lines. Where it is necessary to use catalysts not produced with production manufacturing equipment and processes in certification test vehicles, the issue as to whether or not these catalysts are the same "in all material respects" as production units will arise. Due to the basic nature of the substrates and deposited catalytic materials, it may be difficult to verify that catalyst loading, uniformity of loading, and substrate physical characteristics are indeed representative of quantity production units.

As of the time of data acquisition, there was considerable variability with regard to financial commitments made by the automobile companies (discussed below) and the amount of in-house funds being expended

Table 6-1. Catalyst Suppliers and Products*

Principal Products / Company	Oxidation Catalysts				Reduction (NO_x) Catalysts		Potential Substrate Suppliers
	Base Metal		Noble Metal		Ceramic Substrate	Other	
	Pellet	Monolith	Pellet	Monolith			
Engelhard	--	--	--	PTX series	--	--	American Lava
Grace	Davex 142 promoted with noble metal	--	Davex 145	Davex 502 and 512 (platinum and palladium)	Both pellet and monolith substrates	--	Grace, Kaiser, Pechiney, American Lava, Corning
Gulf	--	--	--	--	Both pellet and monolith substrates	--	Kaiser, American Lava, Corning
Matthey Bishop	-	Base and noble metal mixtures	--	AEC-3A ($15 to $18)	--	--	American Lava, Corning
Monsanto	Recently promoted with noble metal	--	--	--	Pellets	--	Kaiser, Reynolds, Pechiney
Oxy-Catalyst	Promoted with 0.01 to 0.04 oz. of noble metal (~$10)	--	--	Estimated Cost: $40 to $50	--	Metallic monolith type	Kaiser, Reynolds, American Lava, Corning
Universal Oil Products (UOP)	--	--	Platinum/Palladium	Platinum/Palladium	Both pellet and monolith substrates	--	UOP, Kaiser, American Lava, Corning, AC Spark Plug

*Limited to those companies contacted on data acquisition visits.

Table 6-2. Substrate Suppliers and Products*

Principal Products / Company	Substrate Product		Potential User of Substrate Product
	Pellets	Monoliths	
American Lava	--	Cordierite Ceramic, "Thermacomb," stacked or rolled	Engelhard, Grace, Gulf, Matthey Bishop, Oxy-Catalyst, UOP
Corning	--	Cordierite "Extrusion," W-1	Grace, Gulf, Matthey Bishop, Oxy-Catalyst, UOP
Grace	Alumina	Recent development item	Grace
Kaiser	Alumina	--	Gulf, Monsanto, Oxy-Catalyst, UOP
Reynolds	Alumina	--	Monsanto, Oxy-Catalyst
Universal Oil Products (UOP)	Alumina	--	UOP

*Limited to those companies contacted on data acquisition visits.

by the various catalyst manufacturers to remain in a position to be able to compete for potential 1975/76 catalyst requirements. In all cases, there was reasonable confidence that if contract negotiations pending at that time with automobile manufacturers soon resulted in firm production orders, the schedules as shown could be met for oxidation catalysts.

6.1.3.2 Substrate Manufacturer Schedules

Corresponding production lead time schedules currently proposed by representative substrate manufacturers are summarized in Figure 6-4. As was the case with catalyst lead time schedules (Figure 6-3), full production of substrates is planned for the April to July 1974 time period. Again, substrate units required for pre-production stockpiling and/or vehicle certification testing, etc. would be provided from units produced during the plant startup and shakedown period (January to July 1974) or from separate pilot and batch processing lines. Whether or not these proposed production schedules can or will in fact be implemented is of course dependent upon timely receipt of firm production contracts from the automobile manufacturers.

6.1.3.3 Major Schedule Impact Factors

6.1.3.3.1 Plant Design and Construction

In every case, the time required for design of the production facilities, site selection, and construction of the facility or plant is the critical or pacing item in the overall production lead time schedule. Site selection and preliminary facility design activities, at a level sufficient to support the lead time schedules in Figures 6-3 and 6-4, have been or are under way. In some cases this has been covered by contractual guarantees (e.g., Ford Motor Company/Engelhard Minerals and Chemicals Corporation/American Lava Corporation agreements), while in other cases it has been supported by in-house company funds. Actual construction of the production facility will not be initiated by either catalyst or substrate manufacturers until they receive a firm production order contract or similar financial guarantee. At the time of this

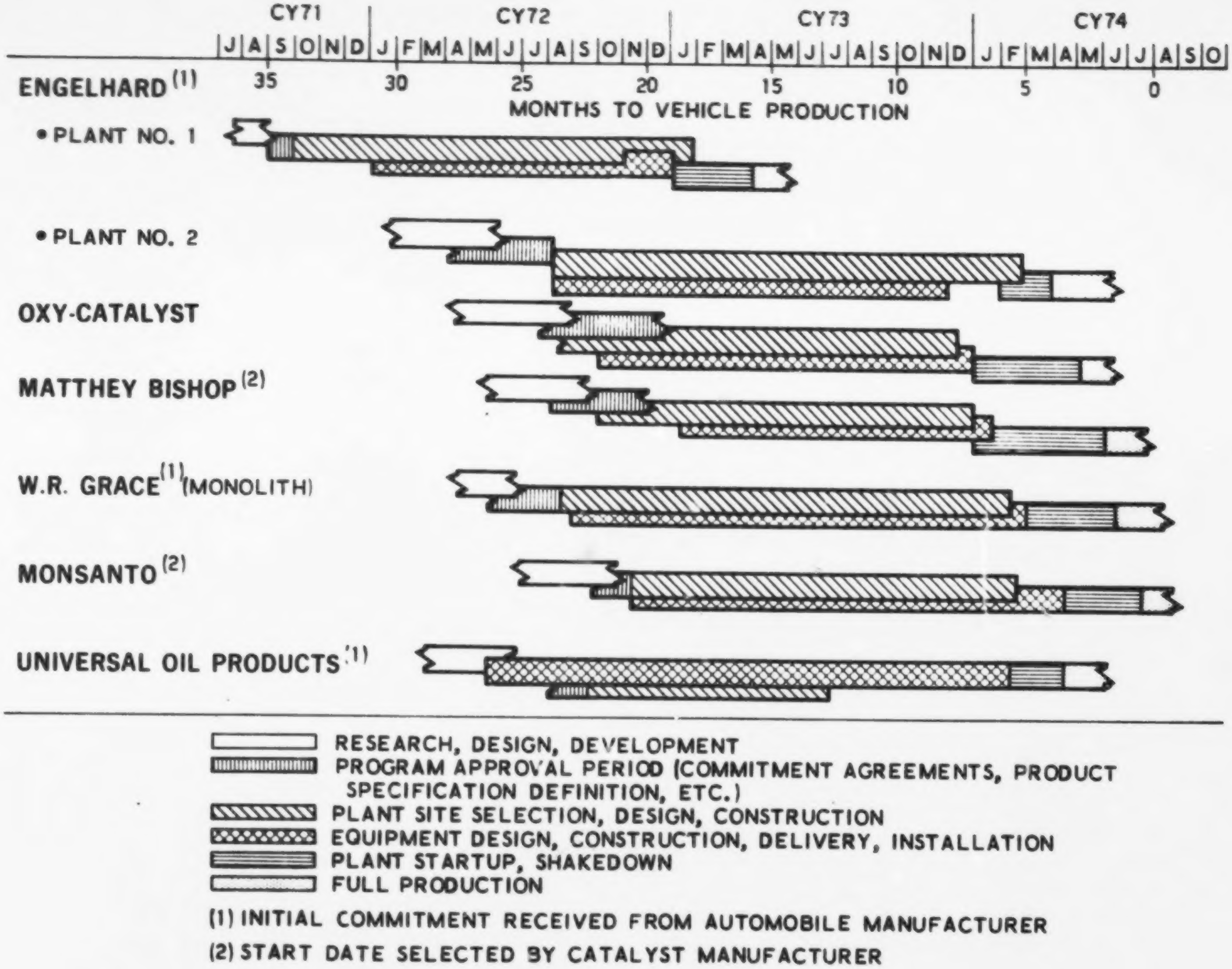


Figure 6-3. Production Lead Time Schedule for Catalyst Manufacturers

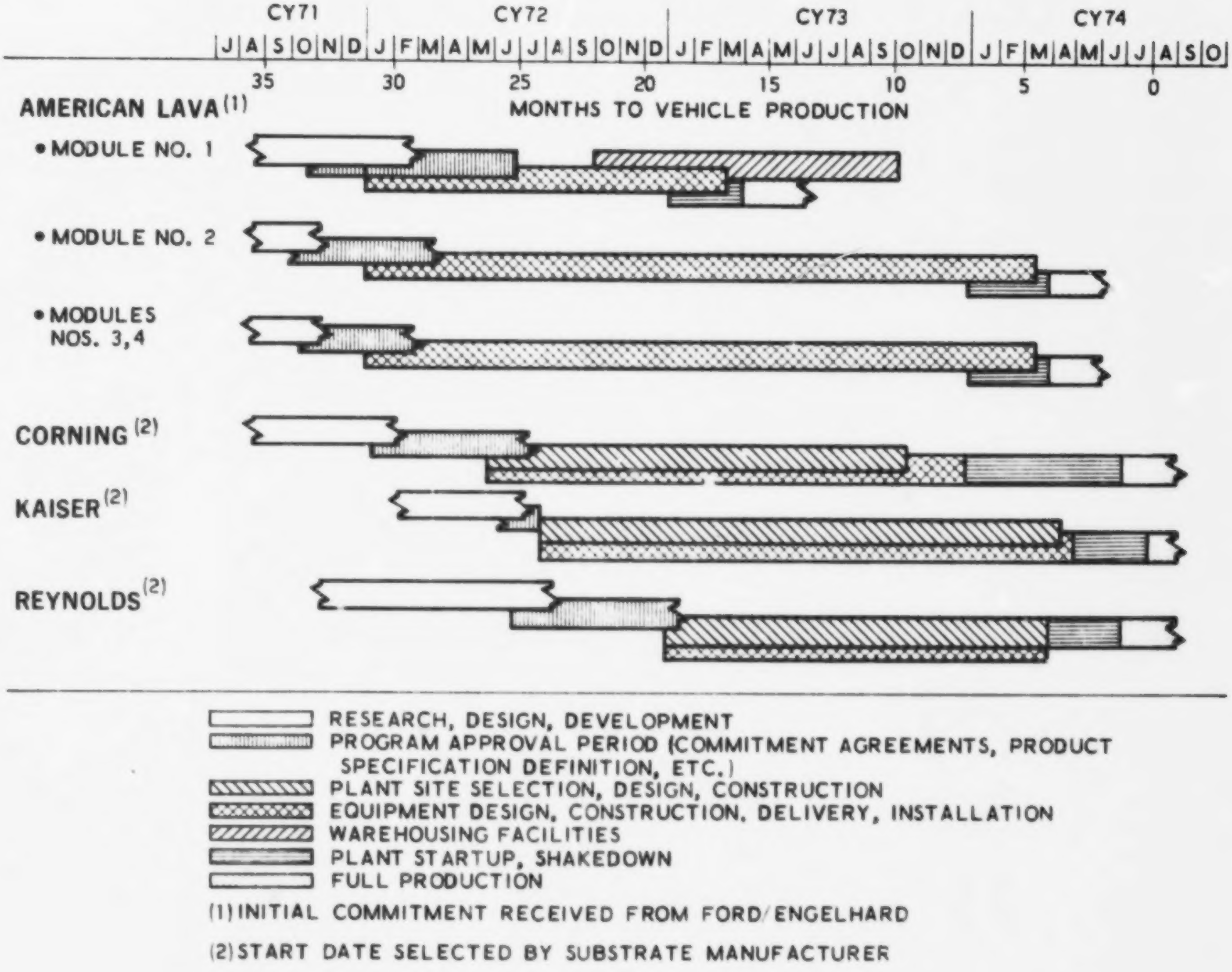


Figure 6-4. Production Lead Time Schedule for Substrate Manufacturers

investigation, negotiations for such production contracts were under way by the major domestic automobile manufacturers and catalyst/substrate manufacturers (discussed in Section 6.1.3.7).

6.1.3.3.2 Equipment and Materials Procurement

Raw materials for substrates and wash coats are considered available in either abundant or necessary quantities and do not materially impact the lead time schedule.

Platinum-group metals (platinum and/or palladium) used as the catalytic agent are considered by the catalyst manufacturers to be available in the lead time schedule time period. The acquisition of these platinum-group metals is considered by most catalyst suppliers to be the province of the automobile manufacturers who are currently negotiating with suppliers in South Africa and the Soviet Union (see Section 11 for full discussion of noble metal availability).

The necessary processing equipment and tools required for both substrate and catalyst manufacturing facilities are largely conventional in nature and do not represent limiting lead time items.

6.1.3.3.3 Plant Startup

Operation of either substrate or catalyst manufacturing facilities is considered to be either simple or routine compared with the operation of a chemical or petro-chemical plant. Allowances of 2 to 6 months have been incorporated in the schedules of Figures 6-3 and 6-4.

6.1.3.3.4 Cost

Available estimates of capital cost requirements per individual supplier are in the range of $4 to $5 million for substrate production facilities and $4 to $15 million for catalyst production facilities, depending upon the projected production capacity. At these cost levels, the substrate and catalyst manufacturers will not commit venture capital without a firm production contract or other form of guarantee. It is this fact which presently strongly impacts the projected schedules of Figures 6-3 and 6-4, since the required production facility construction will not commence until such agreements are negotiated.

6.1.3.3.5 Production Capacity

The production capacity of an individual substrate or catalyst manufacturer impacts the lead time schedule in the sense that the required capacity has to be known in a timely manner in order that the completed facility will have the required capacity. In most cases the catalyst manufacturing plants are being designed as modular units, with the capability to increase capacity by adding production modules; therefore, in these cases production volume currently has little effect on lead time. For example, Matthey Bishop, Inc. requires a commitment by December 1, 1972 to initiate a new plant construction to meet the needs of a given production order. Once initiated, however, a decision regarding additional capacity could be delayed until approximately April 1973 to meet the same full volume production date. (However, orders for substrates might have to be placed before that date.)

6.1.3.3.6 Product Specification Changes

A number of the catalyst manufacturers have indicated that modifications of their currently projected plant equipment and catalyzing process can be incorporated long after the start of catalyst plant construction. Also, substrate modifications in terms of length, shape, and cell structure can be implemented during the next 6 to 8 months. However, catalyst modifications requiring different process line components probably could not be incorporated after placement of the equipment orders.

6.1.3.4 Quality Control and Warranty

In most cases, product specifications have not as yet been specifically delineated and definitive quality control measures have not been completely spelled out. Items of concern include porosity control, wash coat control, noble metal control, substrate breaking and chipping (monoliths), etc. Candidate control techniques include both continuous on-line and batch testing and could include weighing (before and after each process) and destructive testing to verify uniformity and amount of wash coat and noble metal distribution.

It is noted that the mass production of catalysts of these types has never before been accomplished by any company; however, the catalyst firms involved believe that related production and quality control techniques (chemical and petro-chemical industries) provide a firm basis for assurance that quality control requirements will not adversely impact their proposed production lead time schedules.

With regard to warranty, the catalyst and substrate manufacturers plan to warrant only that the finished product meets the product specification requirements. They will not warrant the performance of the finished catalyst as it is installed in the automobile.

6.1.3.5 Pilot Plants

All catalyst manufacturers contacted except the Monsanto Company, Grace, and Gulf have some form of pilot processing production plant in operation. Monsanto has made no decision as to whether or not a pilot plant will be used, while Grace has decided that there is insufficient time to do so and still maintain its projected lead time schedule. Such pilot plants do not directly impact the lead time schedules as shown, but do provide a means for providing quantities of catalyst units needed for pre-production inventory buildup and certification testing, etc., during the period prior to full operation of the completed catalyst production facilities. Where pilot plants are not available, such required quantities would have to be processed in batch production facilities.

In the case of substrate manufacturers (American Lava, Corning Glass Works, Reynolds Metals Company), all have current pilot production capability.

6.1.3.6 Schedule Compression Potential and Effects

With regard to the potential for compressing or shortening the production lead time schedules shown above, the substrate manufacturers have stated, in general, that no appreciable compression can be made at the present level of schedule definition (Figure 6-4).

In the finished catalyst area, there is some hope of minor schedule compressions, as follows:

a. Grace. No schedule compression for monoliths; 3 to 6 month schedule reduction for pellet catalysts at a 10 to 15 cent per pound cost increase (due to premium pay and increased capital cost).

b. Matthey Bishop. One to two month schedule compression for building construction with overtime work (at a negligible product cost increase).

c. Monsanto. Some reduction on plant construction and equipment procurement time. The magnitude of schedule compression and related cost effects are not estimatable at this time.

d. Oxy-Catalyst. Approximately 3 month schedule compression at 10% cost increase due to overtime pay.

e. Universal Oil Products Company. One to 1 1/2 months reduction in facilities construction. The resulting cost penalty is not known.

6.1.3.7 Current and Pending Contract Agreements

6.1.3.7.1 Catalyst Manufacturers

At the time of this investigation (August through October 1972) the status of contractual agreements between the automobile manufacturers and the catalyst manufacturers was one of uncertainty and change because during this period apparently serious negotiations were under way between most of the major domestic automobile manufacturers and the various potential catalyst manufacturers. The following is the status reported as of the time of visits made to the various companies involved (summarized in Table 6-3).

6.1.3.7.1.1 Engelhard Minerals and Chemicals Corporation

Ford has contracted with Engelhard for supplying catalysts to be used in its emission control system, and to date has provided financial backing of up to $4.9 million for production facilities and equipment. According to one source, this agreement would be for meeting ~60 percent of Ford's 1975 catalyst requirements (or up to 3.6 million catalyst units/year). Additional Ford commitments will rise to about $10 million in March 1973 when product design oriented equipment and facilities are ordered, and to $14 million

Table 6-3. Current and Pending Contract Agreements — Oxidation Catalysts and Substrates

Domestic Auto Company / Catalyst or Substrate Supplier	General Motors	Ford	Chrysler	American Motors
Engelhard		~60% of 1975 requirements (up to 3.6 million units/year) Current commitment $4.9 million Could increase to $14 million by April 1974		
Grace	$630,000 engineering commitment Bidding on 25% of 1975 requirements			
Matthey Bishop[a]		Negotiating for ~30% of 1975 requirement (~1.8 million units/year	Negotiating for 25% to 30% of 1975 requirement	
Monsanto	Bid on 1975 requirements			
Oxy-Catalyst	Negotiating			
UOP	Negotiating	Negotiating	Engineering commitment (facility design). Expect production contract for substantial part of 1975 requirements	
American Lava		$300,000 capital guarantee (scale-up of facility for portion of 1975 requirements. Agreement for further scale-up in 1973; negotiating production orders.		
Reynolds	Bid on pellet requirements of potential catalyst suppliers (Davis, Oxy-Catalyst, Monsanto)			

[a] May also be asked to supply all of International Harvester requirements.

by April 1974. These are maximum cancellation agreements providing for reimbursement of Engelhard's nonrecoverable costs in the event of contract cancellation.

6.1.3.7.1.2 W. R. Grace and Company

Grace has received a $630,000 engineering commitment from General Motors covering work in the period from August through December 1972. These funds are for the preliminary design of production plant facilities for both monolithic and pellet catalysts (parallel efforts). Grace is currently completing bid proposals to supply 25% of General Motors oxidation catalyst requirements. While actual bidding operations with other companies are not yet in progress, it hopes to bid on the catalyst requirements of other automobile manufacturers.

6.1.3.7.1.3 Gulf Oil Company

Gulf has no commitment for reduction (NO_x) catalysts from the automobile industry. Since reduction catalysts are not utilized in 1975 model year vehicles, Gulf feels that serious negotiations with the automobile companies will not be instituted before the end of 1973.

6.1.3.7.1.4 Matthey Bishop, Inc.

Contract negotiations are under way with Ford, and Matthey Bishop expects a firm commitment for catalysts from Ford most likely for 30% of Ford's total catalyst requirement for three years (quantities up to about 1.8 million units per year).

Recently, contract negotiations were initiated with Chrysler. Matthey Bishop believes its share of the Chrysler business could be 25% to 30%. Also, Matthey Bishop may be asked to supply all of International Harvester Company's requirements. Conversely, it expects no orders from General Motors or American Motors Corporation. To date, no contracts have been awarded to substrate and materials suppliers (American Lava and Corning are potential substrate suppliers).

6.1.3.7.1.5 Monsanto Company

Monsanto has no commitment for catalysts from any automobile manufacturer. It has no contractual agreements with potential suppliers of plant equipment or catalyst materials.

6.1.3.7.1.6 Oxy-Catalyst Inc.

Oxy-Catalyst has no commitment for catalysts from any automobile manufacturer. However, it is currently negotiating with General Motors.

6.1.3.7.1.7 Universal Oil Products Company (UOP)

UOP recently signed an agreement with Chrysler involving design, engineering, and site preparation of a manufacturing facility with a capability of providing a "substantial part of Chrysler's 1975 catalyst requirements." A separate contract would be negotiated for a specific production output. Current indications are that Chrysler would contract for the monolithic substrate from another source (as yet unidentified).

UOP has also been talking to and negotiating with Ford, General Motors, Volkswagen AG, and Toyota Motor Company, Ltd.

At the insistence of the automobile companies, UOP has agreed (reluctantly) to accept a technology-sharing contractual arrangement which would require it to release its processes, royalty-free, to other automobile company sources of supply.

6.1.3.7.2 Substrate Manufacturers

A similar state of flux characterizes the status of contractual agreements between substrate manufacturers and catalyst or automobile manufacturers. The following is the status reported as of the time of visits made to the various companies involved (summarized in Table 6-3).

6.1.3.7.2.1 American Lava Corporation

American Lava has a formal agreement with Ford for the scale-up of production facilities to meet a portion of Ford's substrate requirements for 1975. Under this agreement, Ford will guarantee the expenditure of American Lava venture capital to the extent of $300,000 through the end of December 1972. A second agreement, of an undisclosed amount, covers additional scale-up of production facilities in calendar year 1973. However, American Lava has not yet received a production order for catalytic substrates, but is actively negotiating this with Ford. The number of production units involved in these negotiations was not disclosed.

6.1.3.7.2.2 Corning Glass Works

Corning does not yet have any contractual commitments from catalyst or automobile manufacturers. It is currently seeking construction cost guarantees similar to the Ford/Engelhard/American Lava agreements.

6.1.3.7.2.3 W. R. Grace

Grace has no commitments for their monolith substrate. Samples have been supplied to Ford, and at its request, to other catalyst manufacturers.

6.1.3.7.2.4 Kaiser Chemicals

Kaiser has no commitments for their pellet substrates.

6.1.3.7.2.5 Reynolds

Reynolds currently has no firm contractual agreements with either catalyst or automotive manufacturers. It has provided quotes on its pellet substrates to Davis Chemical, Oxy-Catalyst, and Monsanto, who were in turn bidding on potential General Motors catalyst requirements in the August through September 1972 time period.

6.1.3.8 Prognosis for 1975 Lead Time Requirements

Based on the lead time schedule projections made by catalyst and substrate manufacturers in the August through October 1972 time period, quantity production of oxidation catalysts for 1975 model year automobiles is possible *if* production order commitments or other acceptable venture capital guarantee arrangements were made by the automobile manufacturers in the November through December 1972 time period. The exact "no go" or "can't make" decision date is difficult to define, because it is intimately related to the level of effort sustained by the substrate or catalyst manufacturer since the schedules (Figures 6-3 and 6-4) were acquired. It is very likely that schedule compression efforts, in the plant construction area in particular, would have to be employed to meet production schedules, at some risk of product cost increase.

Whether or not the automobile manufacturers will make the necessary contractual commitments for 1975 oxidation catalyst requirements, is of course a matter for conjecture only, as it is impossible to predetermine their evaluation of the relative risk factors involved in making such production commitments.

6.2 AMERICAN LAVA CORPORATION

6.2.1 Company Experience and Products

6.2.1.1 Automotive and Nonautomotive Products

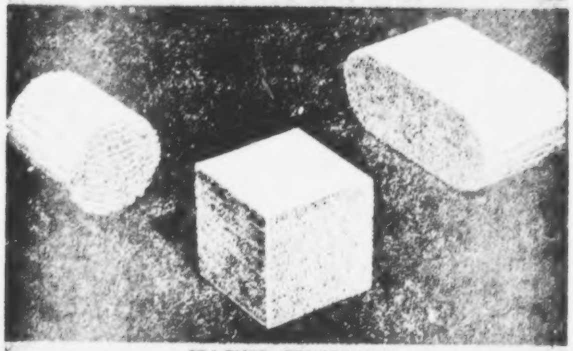
American Lava, a subsidiary of the Minnesota Mining and Manufacturing Company, manufactures a broad spectrum of technical ceramic products which include the Thermacomb Brand corrugated ceramic materials. It has been engaged in the production of Thermacomb ceramics for such applications as catalyst supports for industrial air pollution control equipment, waste heat and gas turbine heat exchangers, and flame arrestors for over 10 years.

Automotive applications have been confined to the development of a catalytic support base, or substrate, for use as an oxidation or reduction catalyst. Two basic forming methods, rolled and stacked, have been used to fabricate the corrugated substrate. Examples of these two types are shown in Figure 6-5. The stacked structure is currently favored for automotive application.

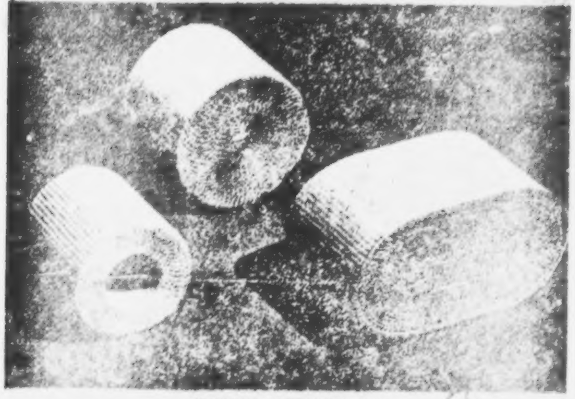
6.2.1.2 Automotive Catalyst-Related Products

The particular Thermacomb ceramic being used by American Lava for the automotive substrate, has as its primary constituent a cordierite material, $2\ MgO \cdot 2\ Al_2O_3 \cdot 5\ SiO_2$, bearing the trade name AlSiMag 795. The corrugation pattern of this stacked monolithic substrate is the split cell configuration shown in Figure 6-6. The current design has 8 corrugations per inch with 0.008 inch wall thickness.

American Lava describes its substrate production process as consisting of three fundamental steps: forming, drying and firing, and finishing. Raw material for the process is received from Minnesota Mining in rolls of cordierite impregnated paper. American Lava corrugates (using techniques similar to those used for the manufacture of cardboard containers), cuts, glues, and stacks the material in large blocks. Moisture picked up in the gluing operation is driven off in a drier. The dried stacks



STACKED STRUCTURES



ROLLED STRUCTURES

Figure 6-5. American Lava-Stacked and Rolled Corrugated Structure

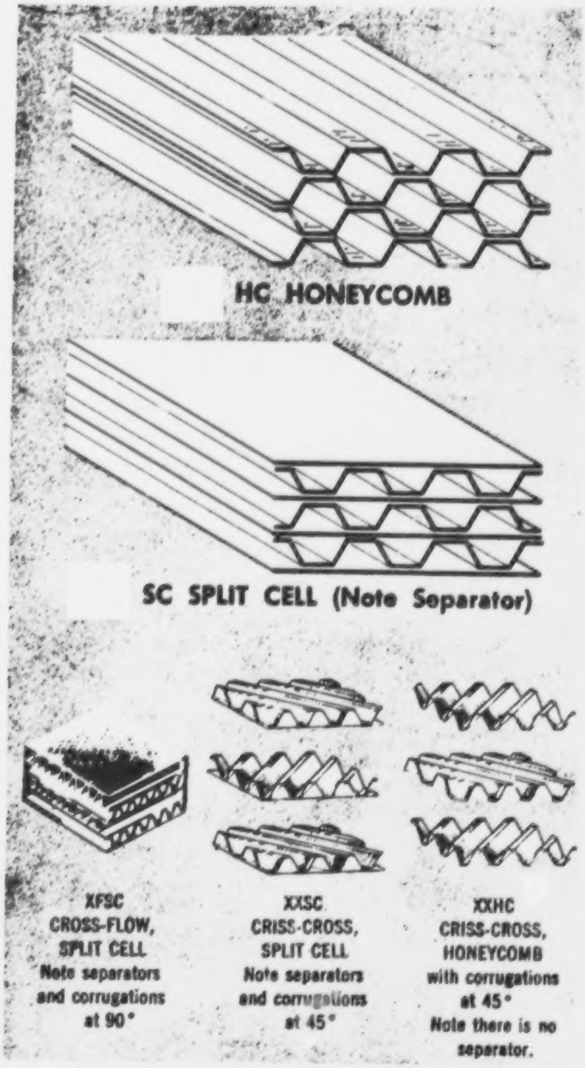

HC HONEYCOMB
SC SPLIT CELL (Note Separator)
XFSC
CROSS-FLOW,
SPLIT CELL
Note separators
and corrugations
at 90°
XXSC
CRISS-CROSS,
SPLIT CELL
Note separators
and corrugations
at 45°
XXHC
CRISS-CROSS,
HONEYCOMB
with corrugations
at 45°
Note there is no
separator.

Figure 6-6. American Lava Corrugated Structure Types

are then fired at 1310°C. Following this the ceramic structure is core drilled to produce a circular cross section, which is then cut to length. The cut pieces are form ground to the specified geometry, e.g., circular or oval (Chrysler apparently is the only manufacturer still considering the oval geometry). Washing, drying and inspection operations complete the procedure.

The finished substrates would be packaged in cartons and shipped (600 substrates per pallet, 56 pallets per box car) to a catalyst manufacturer, such as Engelhard, who would apply the wash coat and catalyst. American Lava states that Engelhard may also apply the belly-band, or cylindrical portion, of the catalyst container. End cones would be applied by fabricators such as Walker Manufacturing Company and Arvin Industries. American Lava indicates that Ford is still not happy with present techniques for mounting the catalyst in the container. One approach uses a spring loaded support and Fiberfrax cement filler. American Lava could spray the Fiberfrax, but it is not actively pursuing this business.

6.2.1.3 Automotive Catalyst/Substrate Test Programs

American Lava does not have an in-house catalyst test program since it produces only the substrate. However, development work on automotive substrate properties and characteristics is continuing.

Historically, American Lava has been a major source of supply for monolithic substrates. These have been evaluated by all domestic and most foreign automobile manufacturers as well as many catalyst manufacturers including Engelhard, Grace, Matthey Bishop, and UOP.

6.2.1.4 Current Research Programs

American Lava has examined other substrate designs. Some of these (unspecified) are still under consideration for automotive use. More corrugations per inch would provide quicker catalyst light off but higher exhaust back pressure. There is also a tradeoff between the number of corrugations per inch and web thickness versus strength. The present design is not yet optimized in this respect.

American Lava is also looking at new substrate designs for possible use in the 1976 production. One of these is an extrusion process. This eliminates the need for the paper base and many of the operations presently used. On the other hand, it feels that the extrusion process produces a pre-loaded structure that is less resistant to thermal stress. It also is not convinced that the process is necessarily a lower cost approach, in view of the high cost of the dies involved and the lack of flexibility in changing substrate geometries. The larger capital equipment at least partially offsets the economic advantage of fewer process operations.

6.2.2 Overall Schedule

6.2.2.1 Normal Production Lead Time Schedule

The manufacturing scale-up schedule that was initially projected by American Lava to produce the monolithic stacked substrate is presented in Figure 6-7. Its basic approach is to develop its production capability on a modular basis. Each module would have a production capacity of 2.25 million units per year, based on a 3 shift per day, 5 day per week schedule.

The first module was planned for completion on a production basis by April 1, 1973. The second module was planned to be ready by July 1, 1973, thereby providing a production capability of 4.5 million units per year only 18 months after the start of the design phase.

Modules 3 and 4, which would bring the total production capacity to 9 million units per year, were planned to be ready by April 1, 1974. These four production modules were planned for construction at the Chattanooga plant, where space could be made available by transferring other operations from Chattanooga to a South Carolina plant.

Additional modules, if required, would be installed in Minnesota Mining's plant facilities outside of Chattanooga, raising the total production capability to 30 million units per year. This represents American Lava's estimate for 30% of the world substrate market in 1976. This number is based on an average utilization of 1.8 oxidizing and 1.8 reducing catalyst units per domestic car and 1.6/1.6 units per foreign car. It was assumed by American Lava

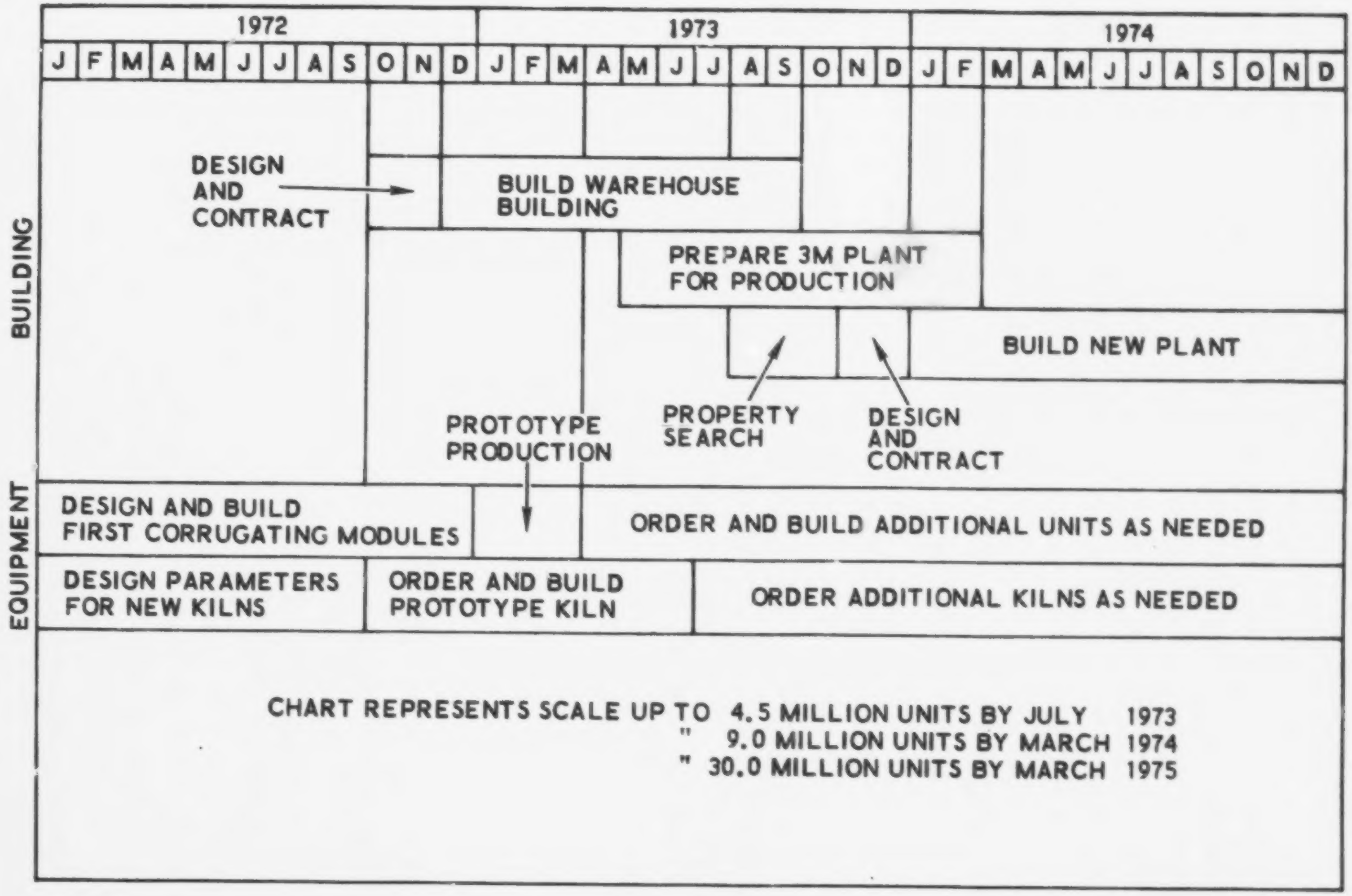


Figure 6-7. American Lava Initially Projected Schedule for Manufacturing Scale-Up

that the same substrate material would be used for both oxidizing and reducing catalysts. The "Build New Plant" phase of its projected schedule (Figure 6-7) would only be put into effect if a requirement arose to supply more than 30% of the world market.

Each production module will require a total of 9,000 square feet of plant space, including the area required for the kilns. This relatively small plant area requirement was said to be due to the unique design of the kilns. The only building construction involved in the development of the 9 million units per year capability at Chattanooga is a warehouse building to house the incoming raw materials. The size of this building is not known.

Under the terms of its agreement with Ford (see Section 6.1.6), American Lava is currently proceeding on a revised schedule for the development of the Chattanooga production facilities (Figure 6-8). The processes developed in its existing pilot operation at Chattanooga will be utilized as a basis for designing these production facilities. The first module is still scheduled for completion in the first quarter of 1973. The second module is now scheduled for completion in the first quarter of 1974. This schedule, reflecting current contract considerations, includes the third and fourth modules which could also be built at Chattanooga. Ford has told American Lava that it would need the maximum annual capacity output (3 shifts per day) for a 13 or 14 week period only.

6.2.2.2 Major Impact Factors

American Lava states that construction of the warehouse for raw material storage is the critical, or pacing, item in the development of the Chattanooga production modules. This must be started by October 1972 to meet the planned schedule. American Lava would not proceed with construction until a piece part contract is obtained.

In response to an inquiry from Ford concerning the latest possible date for making substrate design changes, American Lava indicated that January/February 1973 was the last date for making modifications in

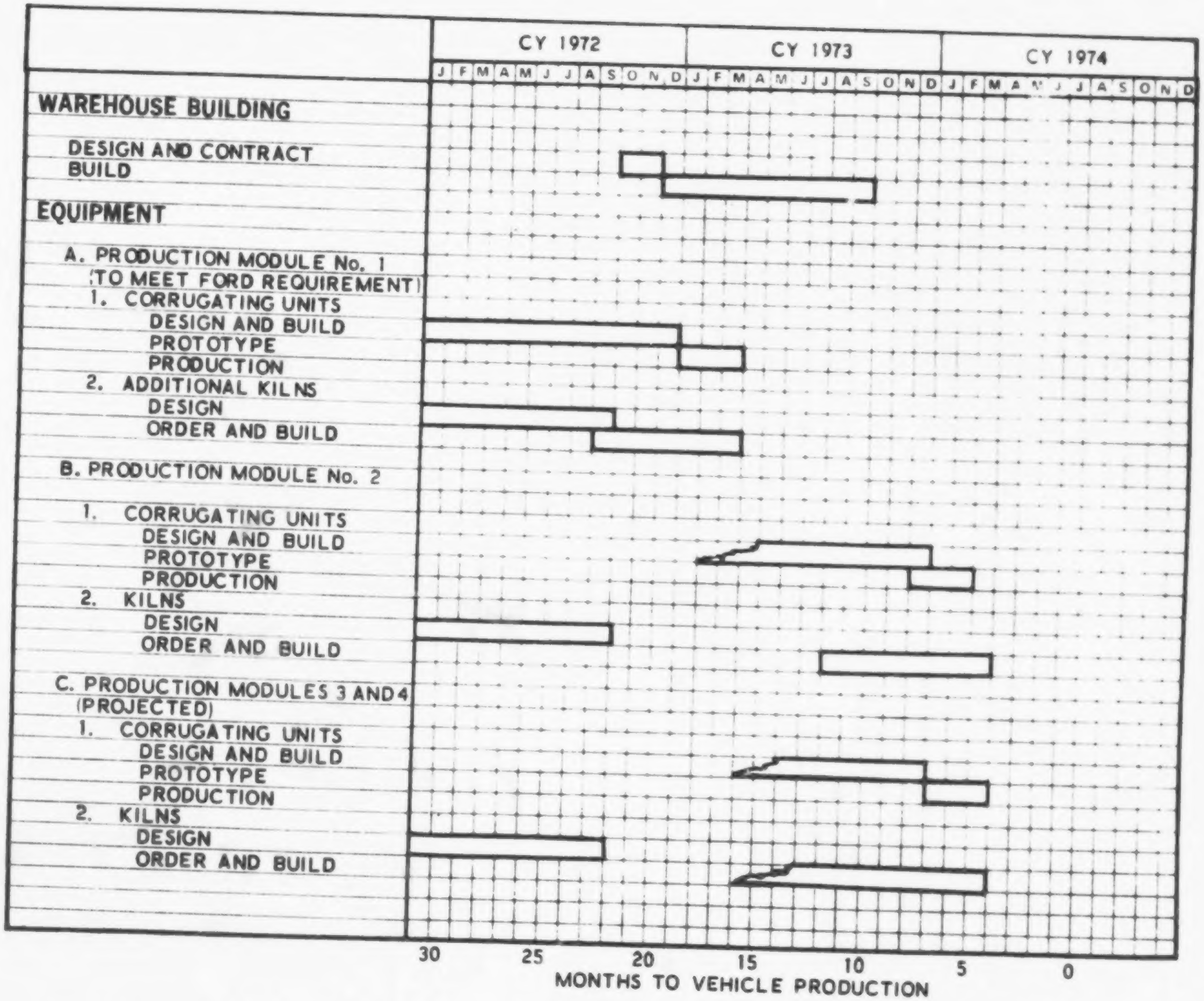


Figure 6-8. American Lava Revised Production Lead Time Schedule (Chattanooga Facilities)

material properties. Deadlines for geometry changes such as web thickness, corrugations per inch, finished configuration, etc., ranged from December 1972 to June 1973. The lead time required for a paper thickness (web thickness) change was specifically delineated as 6 to 9 months.

American Lava also has stated that March 1973 was the latest date on which it could accept an order from General Motors to build substrates for the 1975 model year. As indicated in Figure 6-8, this suggests that American Lava could double the number of production modules at Chattanooga in the succeeding 12 months.

6.2.2.3 Reduction Catalysts

American Lava assumes that the same substrate material will be used for the reducing catalyst as that used for the oxidation catalyst. As discussed in Section 6.2.1.4, American Lava also is looking at new substrate forming techniques, including an extrusion process, for possible use in 1976 production.

American Lava has had discussions with General Motors on designs for the General Motors Triple Mode Emission Control System being considered for possible use in 1976 and has submitted quotes to General Motors. With regard to the two-component system required to meet the 1976 standards, American Lava has been told that pellet catalysts produce higher back pressure and could not be used in series for both oxidation and reduction catalysts.

6.2.3 Major Schedule Elements

6.2.3.1 Plant Design and Construction

As discussed in Section 6.2.2.1, the only building construction which must be accomplished at American Lava's Chattanooga facility is the warehouse required for storage of raw materials.

If a production capacity in excess of 9 million units per year is required, existing space can be prepared for substrate production within a period of 10 months. However, in the event that American Lava required a production capacity in excess of 30 million units per year, a new facility would have to be built. As indicated in Figure 6-7, this would require a total of 17 months. American Lava does not believe that this requirement could be significantly reduced.

6.2.3.2 Equipment and Material Procurement

Process equipment to be used by American Lava includes corrugating machines, cutter/stackers, driers, kilns, diamond-tipped saws and core drills, and diamond form grinders. The form grinders may be either the wheel or belt type; the final choice has not yet been made. An existing tunnel kiln used in the pilot facility will be utilized in the first production module.

American Lava's greatest design effort has been on the forming equipment, i.e., the corrugating machine and the cutter/stacker. It feels, however, that none of this equipment involves development beyond the present state of the art. The cutter/stacker for the first module has been ordered and will be delivered in September 1972. In addition to designing its own corrugating machines, American Lava is having a paper corrugator built as a backup machine. A critical item from the standpoint of cost and continuity of production is the corrugating wheels. At the present time, American Lava is replacing four rollers per week per corrugating unit because of the high abrasive nature of the ceramic impregnated paper and is looking at tungsten carbide rollers as a possible means of reducing the frequency of replacement. The frequency of replacement could create a potential supply problem and affect the continuity of production, particularly if the supplier were to encounter a labor strike.

American Lava has been using form grinders for many years and anticipates no problems in the acquisition of new machines or in the operation of them under mass production conditions.

There are four manufacturers who can supply the required kilns. An existing tunnel kiln will be used in the first module. The second kiln required for the first module was ordered the last week in August and will be delivered March 1, 1973. Two additional kilns are required for the second module. The present kiln design may be modified for the second module but will not create a scheduling problem. The type of drier required has been selected, but the supplier has not yet been chosen. Delivery time on this unit is only 13 weeks.

6.2.3.3 Plant Startup

American Lava has allowed a total of 3 months for plant startup as shown under prototype production in Figure 6-8.

6.2.4 Pilot Plant

American Lava's present output of automotive substrates is produced at a pilot facility at the Chattanooga plant which was generally described as being nonautomated. Production capability of this facility is not known. A portion of the pilot facility (tunnel kiln) will be incorporated into the first production module scheduled to be on-line by April 1,1973.

6.2.5 Current and Pending Contracts

American Lava has a formal agreement with Ford for the scale-up of production facilities to meet a portion of Ford's substrate requirements for 1975. Under the terms of the initial agreement, Ford will guarantee the expenditure of American Lava venture capital to the extent of $300,000 through the end of December, 1972. In the event of order cancellation, American Lava's expenditures for capital equipment would be reimbursed to the extent that these expenditures were nonrecoverable; i.e., that the facilities and equipment could not be used for other American Lava operations. A second agreement, of an undisclosed amount, covers additional scale-up of production facilities in calendar year 1973 with a similar cancellation clause.

American Lava is proceeding on the scale-up of production capability to achieve the completion of the first production module by April 1,1973 and the second module by April 1,1974. It has not yet, however, received a production order for catalytic substrates, but is actively negotiating this with Ford. The number of production units involved has not been disclosed. Construction of the warehouse would not be started until a production contract is signed.

6.3 CORNING GLASS WORKS

6.3.1 Company Experience and Products

6.3.1.1 Automotive and Nonautomotive Products

Corning Glass Works manufactures technical and specialty glass and glass ceramics. Major nonautomotive product lines include electronic and electrical components, optical and ophthalmic glass, consumer ware, and a variety of technical components for industry.

Corning has been involved in an active research and development program on monolithic substrates for automotive catalyst supports since the spring of 1970. In addition it has been involved since 1950 in the manufacture of multi-cellular ceramics for numerous applications, including use as a rotary heat exchanger in gas turbine engines.

6.3.1.2 Automotive Catalyst-Related Products

Corning is actively pursuing the automotive monolithic substrate market. It has done research work on the wash coat and on the application of the catalytic materials, but does not intend to compete for business in these areas.

Early substrate development work by Corning included both the rolled and stacked corrugated substrate configuration in which the cordierite (magnesia/alumina/silica) ceramic material was deposited on a corrugated paper base.

The current Corning substrate, designated as the W-1, was introduced to catalyst and automotive manufacturers in December 1971. The basic material used is also cordierite but the structure is a true monolith rather than a built-up structure as in the case of the stacked or rolled substrate. Corning will not reveal the processes used to manufacture the W-1 but does indicate that it has previously been referred to as an extrusion and that this is acceptable nomenclature for the purpose of discussion. While the present W-1 substrate has a square-cell matrix, the product can be fabricated in a wide variety of cross sectional configurations, as shown in Figure 6-9. The square cell matrix pattern is not considered to be final and the product can be made in hexagonal, triangular or other shapes. Different cell configurations are still being evaluated to determine the optimum configuration from the standpoint of strength, bulk modulus of elasticity, uniformity of coating, etc. Nominal properties of the W-1 substrate are shown in Table 6-4.

6.3.1.3 Automotive Catalyst/Substrate Test Programs

Corning presently is testing substrates in engine dynamometer facilities and on four cars: a Ford, a Chevrolet, a Datsun, and a Volkswagen. Road test data have been used to establish the environmental conditions in its bench testing facility.

Corning has been told that the rotary engine exhaust pulsations impose a particularly severe vibration environment for the substrate which could accelerate breakdown of the substrate structure. Corning has ordered a Mazda to test this condition. No test results are available at the present time.

Corning has supplied W-1 substrate samples to Chrysler Corporation, Ford, and General Motors, in addition to many catalyst and chemical firms, including Engelhard, Matthey Bishop, UOP, Gulf, Monsanto, American Oil Company, Mobile Oil Company, Smith and Associates, Davis Chemical, American Cyanamid Company, and Oxy-Catalyst. It has also provided test samples to European and Japanese auto manufacturers and catalyst manufacturers.

Corning reports that Ford had successfully accumulated 36,000 miles on the W-1 substrate without mechanical breakdown. The emission levels for this test were not necessarily within standards.

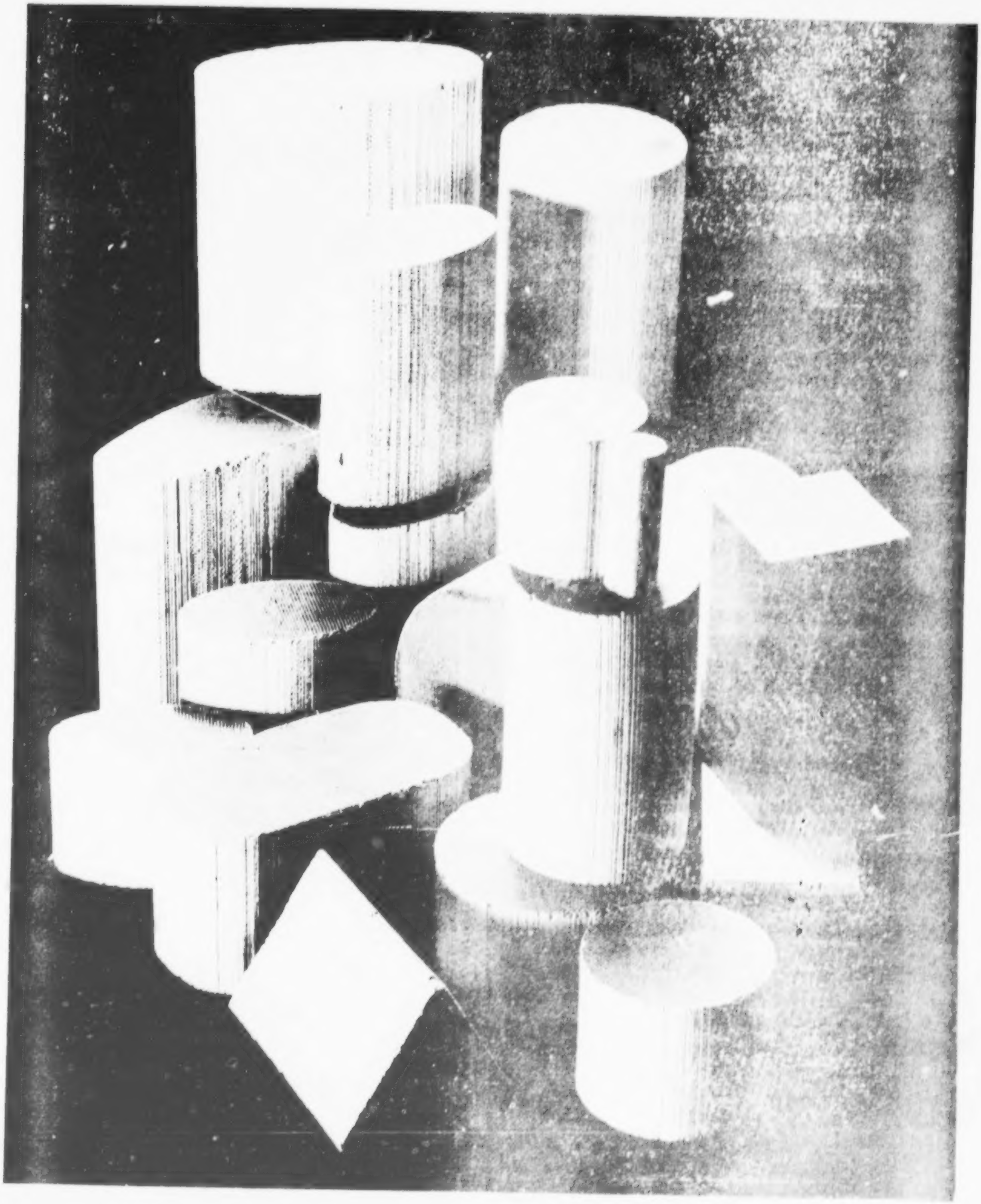


Figure 6-9. Corning Substrate Geometries

Table 6-4. Corning W-1 Monolithic Substrate Nominal Properties

MECHANICAL STRENGTH	
Crushing Resistance	
Axial	5,000 psi
Radial	500 psi
45°	50 psi
*Impact (Cumulative ft-lb - 5 ft drop)	
Radial (140 ft-lb)	8% wt. loss
Axial (140 ft-lb)	3% wt. loss
Vibration (280 cpm, Amp 1.062 in., 80 min)	11% wt. loss
Thermal Expansion (75° to 1830°F)	1.25×10^{-6} in/in°F
*Mounted in Converter Assembly	
STRUCTURAL UNIFORMITY	
Bulk Density	28 ± 2 lb/ft^3
Cell Uniformity (0.06 in. × 0.06 in.	.060 in. to .061 in.
Wall Uniformity (0.010 in. Thick Wall)	.010 in. to .0095 in.
Cells/in.^{2} (0.06 in. × 0.06 In. Cell, 0.01 in. Wall)	203 ± 5
Outside Diameter (Nominal 4-5/8 in.)	± 1/32 in.
Open Frontal Area	74% ± 2%
Porosity - by Mercury Porosimeter	34%
Median Pore Size - by Mercury Porosimeter	7.5 microns

6.3.1.4 Current Research Programs

Corning indicates the following advantages for the W-1 substrate:

a. A more direct fabrication process which requires less labor and fewer process steps, which reduces the cost.

b. The crimping process in the fabrication of the corrugated layered or stacked substrates results in a loss of effective surface area. This does not occur with the W-1 cell matrix geometry.

c. The layered or stacked process produces nonuniform cells and, therefore, nonuniform flow distribution, resulting in less effective utilization of catalyst surface.

d. The heavy protective layer of cordierite on the exterior surface of the W-1 substrate results in a 5000 psi axial crushing strength compared with 2500 psi for the stacked/layered type.

Along with the foregoing advantages, however, Corning has indicated that improvements to the W-1 substrate must be made in two areas before it is ready for release to production. One of these concerns a bonding problem between the W-1 substrate and the alumina wash coat. Catalyst manufacturers have requested that Corning make every effort to improve the bonding characteristics of the cell surface. Although the bonding phenomenon is not well understood by the industry, Corning infers that this problem is primarily identified with high temperature operation. It does not know if other substrate manufacturers are confronted with this difficulty.

The other primary problem to which Corning's development effort is directed is the improvement in the resistance of the substrate to thermal stresses produced by temperature cycling under normal driving conditions.

6.3.2 Overall Schedule

6.3.2.1 Normal Production Lead Time Schedule

Corning is proceeding on the production development schedule shown in Figure 6-10. Corning would build a new manufacturing facility for

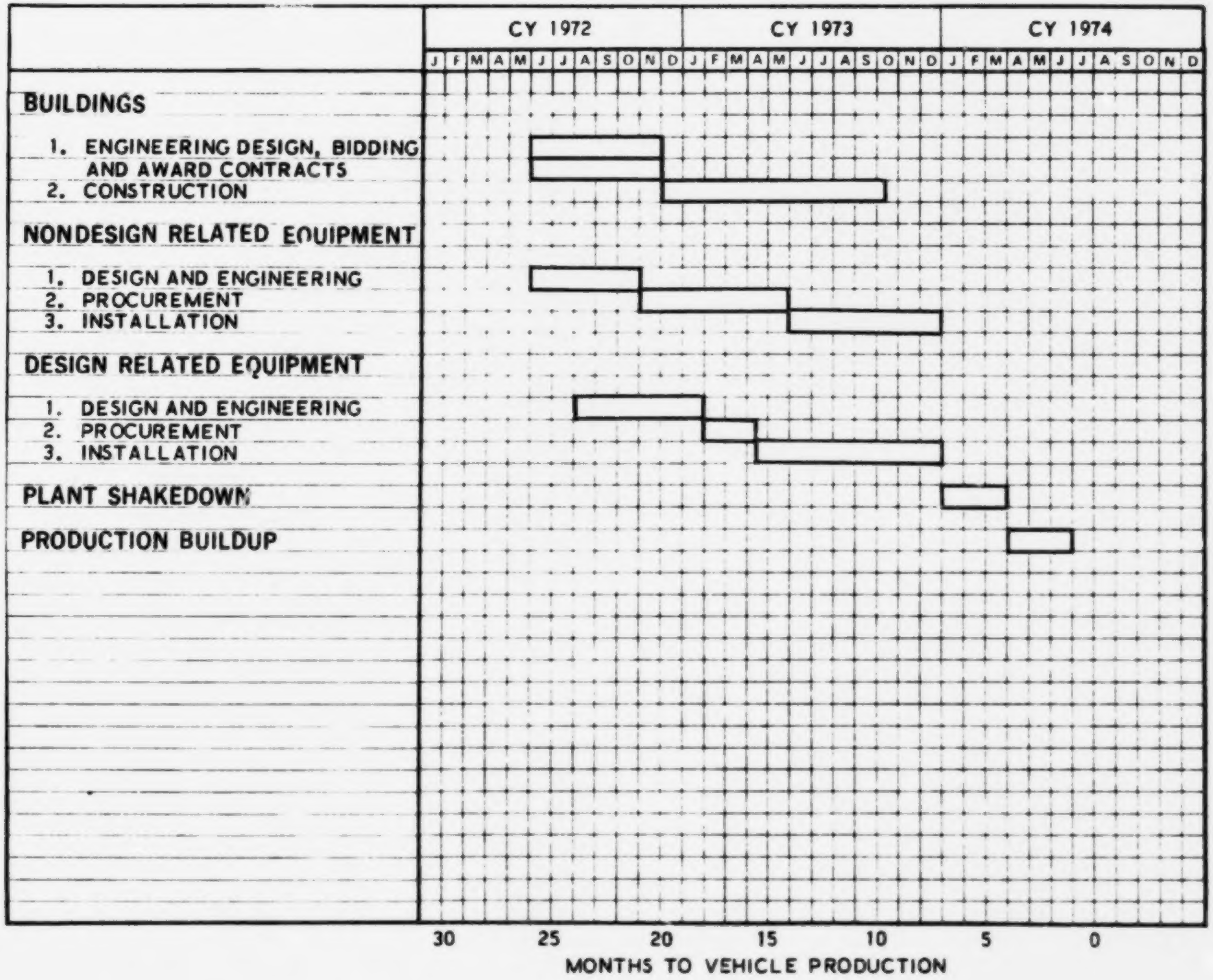


Figure 6-10. Corning Production Lead Time Schedule

1975 model year production. Current planning calls for this facility to be located at the present Corning site.

None of the activities indicated in the schedule have proceeded beyond the design and engineering phases, which, to date, have been undertaken at Corning's expense. Building construction or production equipment orders would not be implemented without a commitment from either a catalyst manufacturer or an automobile manufacturer.

The Corning schedule is based upon a production target of 300, 000 to 900, 000 units per month (3.6 to 10.8 million units per year), although the lack of any commitment to date is reported by Corning to make these goals somewhat academic (see Section 6.3.2.2).

Corning has indicated that a plant size of approximately 100, 000 square feet would be required for the 300, 000 unit per month production rate, although it may represent a production capacity somewhat higher, since it would probably build to accommocate excess capacity. The higher production rates (up to 900, 000 units/month) would require 150, 000 to 200, 000 square feet. It should be pointed out that these square footage requirements may not be directly comparable to those of other manufacturers, since Corning's figures include kilns which are located indoors, whereas other manufacturers may locate them in separate, outside facilities.

Although Corning is comparatively new to the catalytic substrate field, it feels that the foregoing schedule could be achieved based upon the experience gained in the operation of its Company-funded pilot facility. Operation of this facility has contributed to the development of prototype manufacturing equipment and the optimization of its process and product parameters.

6. 3. 2. 2 Major Impact Factors

Corning has stated that there are no critical path items within the framework of its normal production lead time schedule (Figure 6-10). Facility construction time was critical at one time, but new construction techniques used twice previously by Corning have eliminated this item from the critical category. Raw materials are reported to be available in carload lots upon order. The forming equipment used by Corning, while not available off the shelf, could easily be procured within Corning's projected schedule. Tooling and tool construction are also reported as presenting no significant problems.

Corning states that its production schedule is about as tight as it could possibly be. At the time of the meeting with Corning (August 29 1972), it was within the time frame of the schedule and had not had to face any requirements for possible compression as far as production (for the 1975 model year) is concerned. However, a recent telephone contact with Corning brought to light what must be considered the most serious problem impacting its planned production schedule. Because of the fact that it has not received any commitments from potential customers, Corning may decide to defer further production development until a firm commitment has been received. This would mean a slip in the published Corning schedule.

6.3.2.3 Reduction Catalysts

Corning expects the substrate for the reduction catalysts to be used on the 1976 automobiles to be similar to, if not the same as, that used for the oxidation catalyst. On this basis, it feels that a shorter development schedule for 1976 substrate production may be possible, since the manufacturing processes would already have been proven out during the 1975 production.

For 1976 production, a second production facility would be required which would probably be built at a different location to ensure that labor is available for a minimum production output at all times.

6.3.3 Major Schedule Elements

6.3.3.1 Plant Design and Construction

Plant design is being carried out by Corning at its own expense as a part of its in-house effort toward the development of the production schedule discussed in Section 6.3.2.1. As indicated in Figure 6-10, the design engineering, bidding and contract awarding phases were scheduled to be completed by December 1,1972, followed by a 10-month construction period scheduled for completion early in October, 1973. Building design is based upon new construction techniques used by Corning on two previous occasions. Construction would not be started without a commitment from a potential customer.

As previously pointed out, the Corning in-house effort may be deferred until such a commitment is received. The effect of such a deferment on the ability of Corning to meet its proposed schedule is unknown at the present time.

6.3.3.2 Equipment and Material Procurement

There are no lead time problems associated with Corning's raw material requirements. Sources of supply have been identified and the raw materials will be available upon order. Corning declines to identify its source of raw materials, indicating that this information might reveal to its competitors the chemical properties of its cordierite supply.

Equipment involved in the production of the W-1 substrate is generally described by Corning as consisting of blenders, mullers (mixers), "forming equipment", drying and firing kilns, and cutters. Corning will not be more specific as to the nature of the process equipment since it considers this to be proprietary information.

The "forming equipment", although not an off-the-shelf item, is reported to be generally available to the industry. Corning would order such equipment to its own specifications or modifications. Such equipment would be readily available within the time frame of its production schedule. Tooling and tool construction are also reported as not being a significant lead time consideration.

As shown in Figure 6-10, Corning has indicated two basic categories of equipment, i.e., nondesign and design related equipment. The nondesign related equipment refers to such items as raw material processing equipment, e. g., blenders, mixers, and other equipment not dependent on a knowledge of the finished dimensions of the product. Design related equipment would be dependent on knowing the finished dimensions. As shown in its schedule, Corning states that design related equipment would have to be ordered by January 1,1973. This would be the last date to define the production geometry to be used.

6.3.3.3 Plant Startup

Corning has allowed a three-month period starting January 1, 1974 for plant shakedown followed by an additional three-month period for production buildup to 100% capacity. This six-month interval appears to be two to three months longer than that reported by other substrate manufacturers and could possibly represent some margin for schedule compression.

6.3.4 Quality Control and Warranty

Corning reports that firm specifications on the substrate have not yet been established by the auto manufacturers and that it can not define any warranty requirements on their part. Corning is working with the catalyst processors to define and develop suitable strength and adherence properties. Auto manufacturers are expected to provide only gross specifications, such as maximum back pressure, overall dimensions, etc.

6.3.5 Pilot Plant

The present capacity of the pilot plant is reported by Corning to be 1500 to 3000 units per month. Original planning by Corning called for additional equipment to be added during the next six to seven months which would raise the production capacity to 30,000 or more units per month by

June 1973 to permit catalyst manufacturers to build an adequate inventory for preproduction trial runs in 1974. However, this program might be curtailed in view of the absence of commitments from the automotive industry.

6.3.6 Current and Pending Contract Agreements

Corning has not yet had any contractual commitments from catalyst processors or auto manufacturers.

Corning feels that the auto manufacturers would have the final word on who will supply substrates to their catalyst suppliers and expects to contract directly with the auto firms to supply substrates to the catalyst manufacturers. Corning is currently seeking guarantees that facilities construction costs would be covered in the event of an order cancellation, similar to the Ford/Engelhard/American Lava agreements.

6.4 ENGELHARD MINERALS AND CHEMICALS CORPORATION

6.4.1 Company Experience and Products

6.4.1.1 Automotive and Nonautomotive Products

Engelhard is a major refiner of precious metals, and a major manufacturer of precious metal catalysts and products used by the chemical, petro-chemical, petroleum, and pharmaceutical industries for processing and pollution control for more than 20 years.

For several years Engelhard has been engaged in the development of oxidation catalysts for potential use in automotive exhaust emission control systems. Engelhard does not manufacture the catalyst substrate, but it does apply the wash coat and the catalyst materials to the substrate.

6.4.1.2 Automotive Catalyst-Related Products

Engelhard's principal automotive oxidation catalyst product is a noble metal (platinum) monolithic catalyst. The primary monolithic substrate utilized to date by Engelhard is the corrugated ceramic (Thermacomb) produced by American Lava in both the stacked and rolled configurations (see Section 6.2). The Corning W-1 monolithic substrate (see Section 6.3) could also be used.

The standard Engelhard PTX catalyst has been under development for automotive application for some time. More recently Engelhard has been concentrating its efforts on an improved version of the PTX. According to Engelhard this new formulation has better high-temperature stability and improved lightoff characteristics.

6.4.1.3 Automotive Catalyst Test Programs

Engelhard has an extensive in-house catalyst research, development and test program. Laboratory facilities are available for evaluating catalyst activity both adiabatically and isothermally. To date, more than 600 different catalysts have been screened in the laboratory.

Six engine dynamometers, a chassis dynamometer, and up to six test cars are available at Engelhard's auto exhaust test facility.

Also Engelhard has been supplying PTX catalysts to both domestic and foreign auto manufacturers for use in their evaluation programs.

6.4.1.4 Current Research Programs

Engelhard's catalyst research is concerned primarily with new substrate configurations and improved catalyst formulations (part palladium) in an effort to improve the lightoff characteristics and durability of its catalysts.

6.4.2 Overall Schedule

6.4.2.1 Normal Production Lead Time Schedule

The Engelhard catalyst production capability is being developed in two phases. The first phase covers the development of a pilot plant facility, Plant No. 1, and is designed to evolve a mass production technology for performing wash coat and catalyzing operations on a monolithic substrate supplied by outside sources: (e.g., American Lava or Corning). The technology developed in the pilot operation (Plant No. 1) is planned to be incorporated into a main plant production facility (Plant No. 2). The production capacity of the pilot plant would be combined with that of the main plant to provide Engelhard's total output capacity. Engelhard will wholly own these facilities.

The Engelhard schedule for the completion of Plant No. 1 is shown in Figure 6-11. This schedule indicates that mechanical completion of Plant No. 1 will be accomplished by January 1, 1973 with full production capability achieved by April 1, 1973. The capacity of Plant No. 1 will be 1.5 million units per year, based upon a 3-shift-per-day, 5-day-per-week operation.

The schedule for Plant No. 2, shown in Figure 6-12, calls for completion in January 1974, with the exception of painting and insulation, with full production to start March 15,1974. Engelhard feels that Plant No. 2 will require a slightly longer period to complete than Plant No. 1.

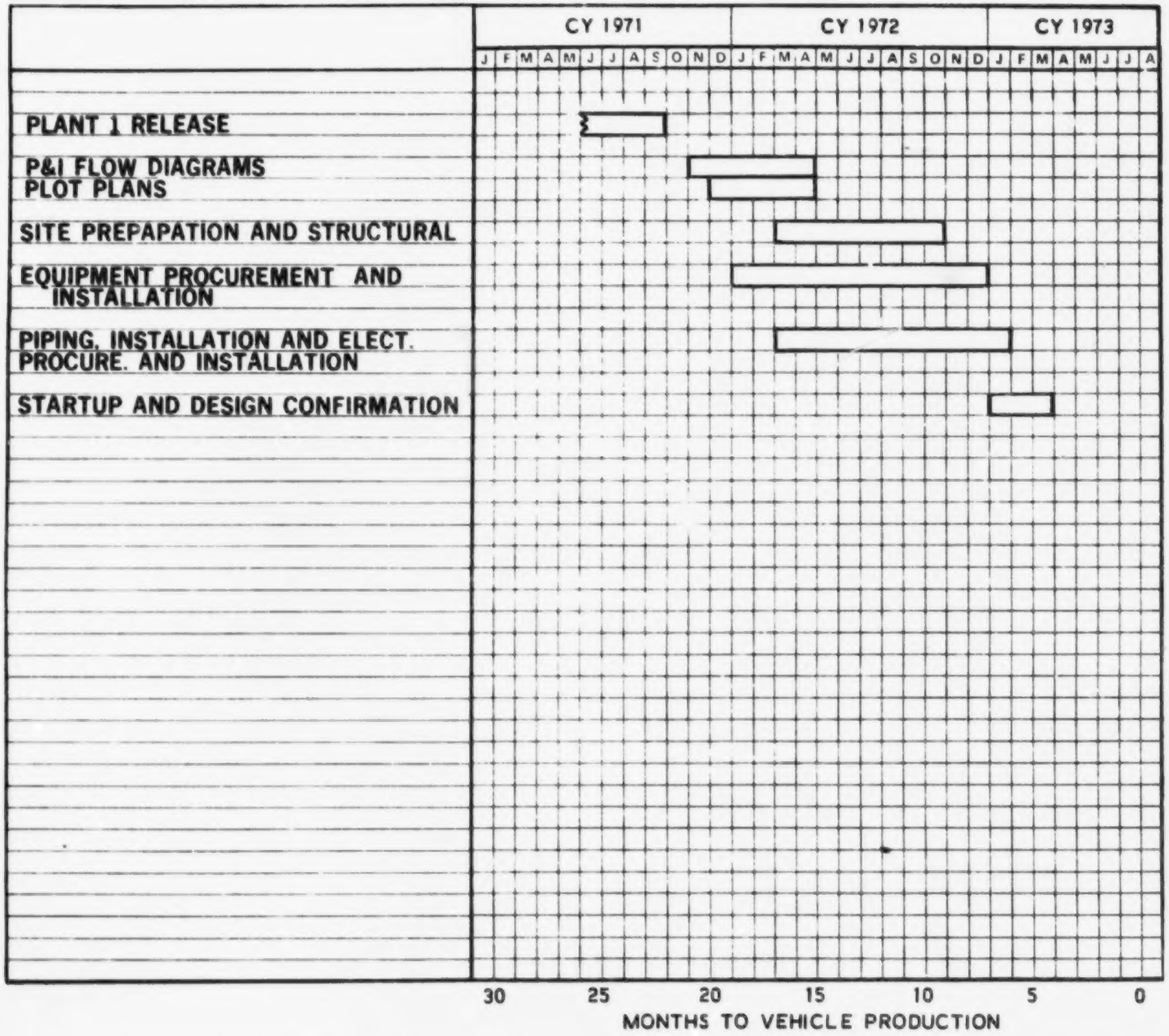


Figure 6-11. Engelhard Production Lead Time Schedule, Plant No. 1

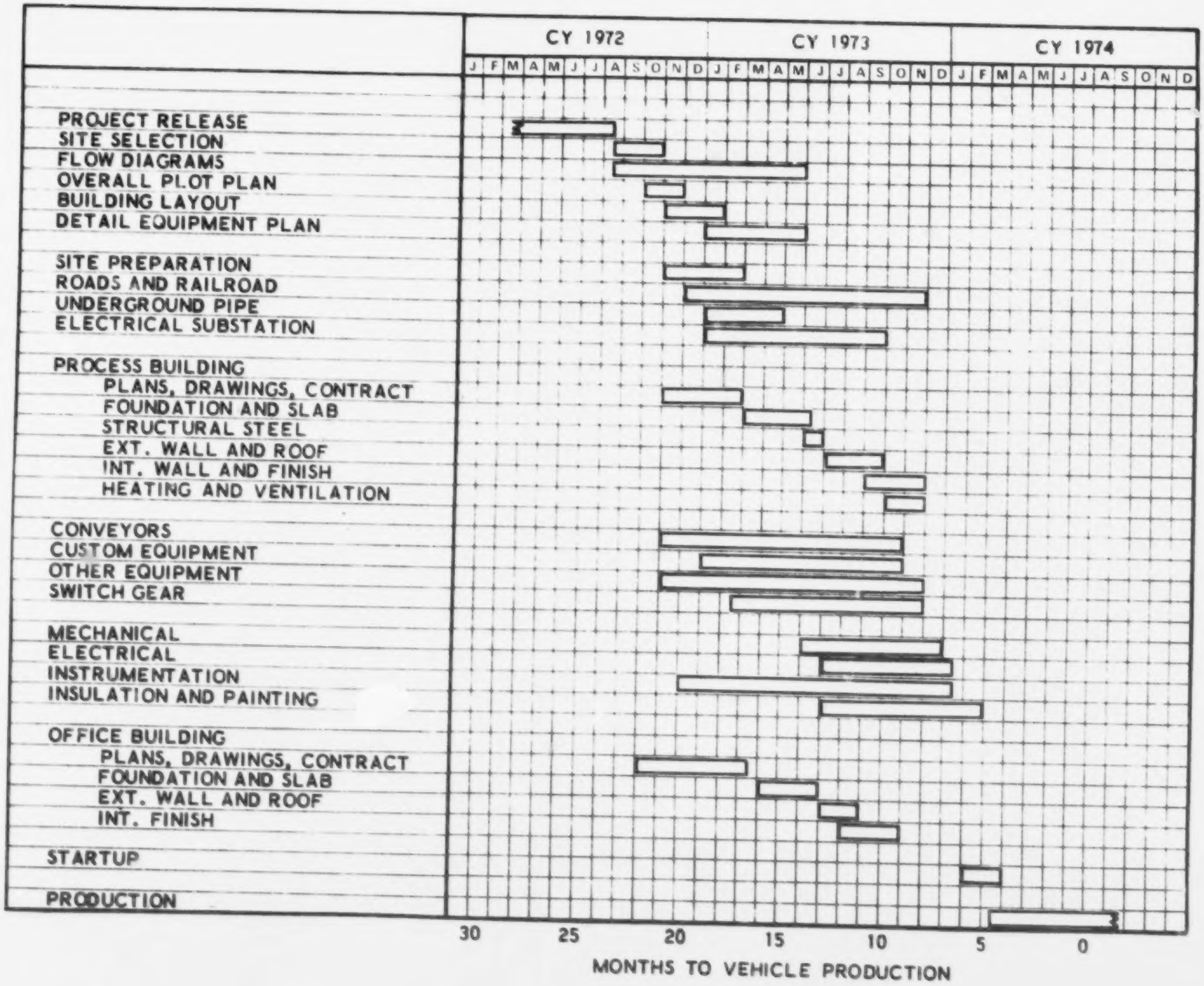


Figure 6-12. Engelhard Production Lead Time Schedule, Plant No. 2

A final decision has not yet been made regarding the size and production capacity for Plant No. 2. If started now, the plant could be built within the time frame indicated in Figure 6-12 with a production capacity approaching 10 million units per year by April 1974.

6.4.2.2 Major Impact Factors

Two major impact areas are pointed out by Engelhard with regard to its catalyst production schedule to meet 1975 model year demands. The first is related to the plant size and capacity needed to meet customer demands over and above the existing commitment to Ford (see Section 6.4.6). Currently this total demand for Engelhard's automotive catalysts is unknown.

The second major impact area relates to the availability of adequate supplies of platinum in time to meet the production requirements for the 1975 model year. According to Engelhard the deadline for platinum suppliers to open new mines was October 1,1972. Engelhard will buy 99+% pure metal platinum which it will then refine further to achieve the required purity of 99.995%. Delivery of the platinum from the mines is required three months before startup of the catalyst plant.

A detailed discussion of the overall platinum availability is included in Section 11.

6.4.3 Major Schedule Elements

6.4.3.1 Plant Design and Construction

As indicated in Figure 6-11, the Plant No. 1 (pilot) facility will be completed, including piping, instrumentation and electrical procurement and installation, on February 1,1973, 16 months after the release date.

The Plant No. 2 facility, including mechanical, electrical and instrumentation procurement and installation will be completed by January 15,1974, as shown in Figure 6-12. Insulation and painting work will be completed March 1,1974, 18.5 months after program go-ahead.

6.4.3.2 Equipment and Material Procurement

The plant equipment required for Plant No. 2, e.g., calciners, driers, conveyors, etc. will extend the completion interval over that required for Plant No. 1. However this is not expected to prevent the completion of Plant No. 2 within the schedule required to meet the projected production startup date of March 1, 1974.

As discussed in Section 6.4.2.2, Engelhard refers to certain lead time problems associated with the development of additional platinum mining and processing capability as having a possible impact on the availability of raw materials.

6.4.3.3 Plant Startup

Engelhard has scheduled a three month period for Plant No. 1 startup and design confirmation commencing on January 1, 1973. Full production capacity will be achieved on April 1, 1973.

Two months have been scheduled by Engelhard for the startup of Plant No. 2 with production starting March 15, 1974.

6.4.4 Quality Control and Warranty

Engelhard will warrant its automotive catalysts only for quality of materials and construction, but not for catalyst performance in the vehicle.

6.4.5 Pilot Plant

The Engelhard pilot plant (Plant No. 1) facility is discussed in Section 6.4.2.1 in connection with the development of Engelhard's overall production capability.

6.4.6 Current and Pending Contractual Agreements

Engelhard has a contract with Ford to supply a portion of Ford's converter requirements for 1975 through 1977. The Engelhard operations will include the application of the wash coat and the noble metal catalyst to a monolithic substrate supplied by other sources such as American Lava. Packaging of the catalyst in a metal canister will be done outside by manufacturers such as Walker Manufacturing Company and Arvin Industries. In addition, Engelhard is negotiating with other domestic and foreign automobile manufacturers.

The first Ford commitment agreement with Engelhard was made in 1971 concerning the development of a catalyst pilot plant. At that time Ford and Engelhard committed funds totaling \$2.4 million, presumably for plant site procurement and initial construction. Half of this amount consisted of nonrecoverable Engelhard funds. The next commitment to Engelhard by Ford was made in March 1972 and amounted to a \$3.7 million capital investment guarantee to Engelhard by June 1972.

An additional commitment was made by Ford in August 1972 dealing with the development of the Plant No. 2 facility. Ford commitments to Engelhard plant development will rise to about \$10 million in March 1973 when product design oriented equipment and facilities are ordered, and to \$14 million by April 1974. These are maximum cancellation agreements providing for reimbursement of Engelhard's nonrecoverable costs in the event of cancellation.

In addition to the facilities development commitments above, Engelhard has a three-year contract from Ford to supply Ford with one half million troy ounces of platinum per year for the 1975/77 time period. The platinum will be procured by Engelhard from Rustenburg Platinum Mines, Ltd. of South Africa. The contract was reported by Ford to be written on a price-protected, no-cost-for-cancellation basis.

6.5 W. R. GRACE AND COMPANY

6.5.1 Company Experience and Products

6.5.1.1 Automotive and Nonautomotive Products

The Davison Chemical Division of Grace is one of the country's leading suppliers of petroleum cracking catalysts and a number of industrial catalysts such as phthalic anhydride catalysts and Raney nickel. Currently, Grace produces large amounts of these catalysts for the petroleum industry. These catalysts are of the silica type and contain no metal of any kind.

Aside from potential automotive catalyst and/or substrate products, Grace does not supply products to the automotive industry.

6.5.1.2 Automotive Catalyst-Related Products

Grace's principal potential automotive products include the following:

1. Pellet oxidation catalysts
   - a. base metal (Davex 142)*
   - b. noble metal (Davex 145)
2. Monolith oxidation catalysts
   - a. noble metal (Pt/Pd) (Davex 512 and Davex 502)
3. Pellet substrates
4. Monolithic substrates
5. Reduction catalysts (monolithic or pellet substrates)

In the case of both oxidation and reduction catalysts, the substrate could either be made by Grace or procured from outside vendors. Kaiser Aluminum and Chemical Corporation and Pechiney are preferred pellet suppliers. American Lava and Corning are being considered as outside monolith suppliers.

---

*Promoted (small amounts of noble metal), to improve lightoff characteristics.

6.5.1.3 Automotive Catalyst Test Programs

Grace's in-house catalyst program consists of the following:

1. Producing experimental quantities of catalyst support materials for both pellet and monolithic catalysts.
2. Generating experimental formulations of catalysts on pelleted materials and monoliths, with base metal and noble metal catalytic materials, both for oxidation of hydrocarbons and carbon monoxide and the reduction of nitrogen oxides.
3. Evaluating the effectiveness of such catalyst formulations in laboratory screening units.
4. Evaluating the effectiveness of the more promising catalysts on automobiles with the EPA test schedule on a chassis dynamometer.
5. Evaluating the stability of catalyst activity by "aging" full-sized containers of catalyst on a test stand dynamometer for the equivalent of up to 5000 miles.

Grace does not conduct vehicle road testing for catalyst durability, and is not involved in any development work on the design of catalytic converters.

Also, Grace has supplied catalysts to various automobile manufacturers for use in their own emission control programs, including General Motors, Ford, Chrysler, American Motors, International Harvester Company, Volvo, Inc., Saab-Scania, Volkswagen, Daimler-Benz AG, Fiat, Peugeot, Toyota, and Nissan Motor Company.

6.5.1.4 Current Research Programs

Grace is continuing to develop catalytic formulations with improved effectiveness characteristics.

In the case of monolithic substrates, Grace is developing an in-house product, of proprietary construction. Catalysts using the Grace monolithic substrate have recently been submitted to a number of automobile manufacturers. To date, Grace has not received definitive information from the manufacturers regarding the performance of these catalysts.

Grace is also working on a new monolith mounting system. It feels that the stainless steel mesh coverings and end flanges used by some manufacturers for monolith substrate protection have not worked well for the auto companies. Grace feels its new approach has promise to solve the problem.

6.5.2 Overall Production Schedule

6.5.2.1 Normal Production Lead Time Schedule

Grace's estimated normal production lead time schedule for oxidation catalysts is essentially unchanged from previous estimates. It is based on the need for entirely new and different plants for the pellet and monolithic catalysts (no existing production capacity; current catalysts produced via processing lines with no prototype pilot plant). The major schedule milestones are presented in Table 6-5.

Table 6-5. Grace Major Schedule Milestones

Milestone	Lead Time, Months	
	Pellet Catalyst	Monolithic Catalyst
Start of engineering; commitment by customer	24	22
Critical equipment ordered; start of construction	21	19
Critical equipment delivery	9	7
Plant completion	3-4	3-4
Plant shakedown	2	2
Full production	Time 0	Time 0

Grace estimates such production facilities could cost in the range from \$5 to \$15 million, with detailed engineering costs representing approximately 10% to 15% of the overall plant investment cost.

6.5.2.2 Major Impact Factors

Grace considers that the most critical lead time item is the construction of the catalyst plant itself, which consumes from 16 to 18 months (Grace feels that plant leasing is not feasible). Then follows the substrate procurement time period. While Kaiser has estimated up to 30 months for its lead time requirement, Grace feels it can build its own alumina (Al_2O_3) pellet plant in the same time frame as the catalyst production plant. In the case of monolith supports, Grace estimates a lead time requirement of approximately 20 to 22 months. American Lava has stated a 24-month requirement, and Corning an 18-month requirement.

The processing and handling equipment is conventional in nature and can be procured within the time frame set for plant construction (e.g., furnaces, kilns, mixers, etc. -- 10 to 12 months).

In the case of alumina pellet substrates, Grace has the capacity (with modifications to existing facilities) to produce 15 to 20 million pounds per year, using hydrated alumina purchased from outside sources. Since 100% of the General Motors pellet requirements could be as high as 50 million pounds per year, outside pellet suppliers would be required if Grace was selected as General Motors sole catalyst supplier. However, Grace feels that 2 or 3 catalyst suppliers might be selected by the big automobile manufacturers. During the past 9 months it has worked primarily with its own substrates, since most of the pellets supplied by outside vendors have shown excessive variability in the physical properties of the pellets.

Grace feels that no schedule compression is possible for its monolith catalysts (the full 22 months' lead time is needed because of a lack of experience in that area). The pellet catalyst lead time could be compressed by three or possibly even by six months at a 10 to 15 cent per pound cost increase (premium pay to equipment manufacturers and increased capital cost of the production facility). In both cases, improvements in the catalyst substrates and formulations can be implemented long after the start of plant construction.

6.5.2.3 Reduction Catalysts

No production scheduling problems are currently foreseen for reduction catalysts, which could be produced at these facilities. The same basic processes are involved whether the substrates are pellets or monoliths.

6.5.3 Major Schedule Elements

6.5.3.1 Plant Design and Construction

Grace is currently having an outside contractor perform the preliminary design of production plant facilities for both monolithic and pellet catalysts (parallel efforts). Grace is providing only in-house surveillance of the design activities. An outside contractor would be selected by Grace to build the production facility. Again, Grace would perform in-house surveillance during the construction period.

6.5.3.2 Equipment and Material Procurement

The major pieces of the required plant and process equipment have not yet been fully identified; the just-initiated plant engineering effort should result in a complete identification of the required equipment. In the case of the Grace in-house monolithic substrate, the equipment types are not known; however, for the pellet substrates and catalyst finishing operations, conventional equipment would be required; e.g.,

a. Pellet substrates (mixers, extruders, cutters, dryers, heat treaters, drive motors, etc.)

b. Finished catalysts (mixing and holding tanks, pumps, spraying equipment, dryers, calciners, etc.)

Grace has conventional arrangements for the supply of raw materials (alumina, catalyst metals, etc.) and substrates (pellet or monolithic). The platinum and palladium supply would probably be secured by direct agreements between the auto companies and the platinum/palladium producers. (Grace feels that less than 0.1 ounce of noble metal would be required for noble metal catalysts.) However, Grace is also conducting negotiations with noble metal suppliers in South Africa and with the Soviet Union.

6.5.3.3 Plant Startup

Grace feels that such catalyst manufacturing plants and their operations are not complex, in comparison with chemical plants, and therefore foresee no difficulty in initial plant startup activities following plant completion.

6.5.4 Quality Control

Grace does, however, envision several quality control problems which might exist for monolithic catalysts, since there has been no mass-production experience by anyone in the field. These problems include, porosity control, wash coat control, noble metal control, substrate breakage, and substrate chipping.

To minimize substrate breakage and chipping, Grace feels that it might be advisable to put the outer container shell on the monolith at the catalyst plant to protect it in further handling/shipping operations. It does not recommend that any end closures or weldments be done at the catalyst plant, however.

Final quality control specifications have not yet been set. For monolith catalysts, the monolith would probably be weighed at each step of the process to determine loadings (wash coat, amount of platinum, etc.). Destructive tests would probably be used to ensure uniformity of wash coat and platinum distribution.

6.5.5 Pilot Plant

Grace has not established a pilot production plant and does not plan to do so as there is insufficient time remaining.

6.5.6 Current and Pending Contractual Agreements

Currently, Grace is completing bid proposals to supply 25% of General Motors' automotive oxidation catalyst requirements in both the pellet and monolithic areas. These proposals are based on a monolith catalyst plant that can be converted to pellet catalyst production.

In addition, Grace has received (approximately August 17 to 18, 1972) a $630,000 engineering commitment from General Motors to cover the period until the end of 1972 (funds may actually be spent by November 15, 1972). These funds are to be used for preliminary design of production plant facilities for both monolithic and pellet catalysts (parallel efforts). Grace is working with an outside contractor in this regard and would provide only in-house surveillance of the design and construction activities.

While actual bidding operations with other auto companies are not yet in progress, Grace also hopes to bid on the catalyst requirements of other auto companies. However, in view of its currently projected limited capability for producing pellet catalysts for 1975, Grace will be forced to limit its pellet catalyst bids. In the case of monoliths, it would be willing to proceed with the program on a risk basis if commitments were received before the end of 1972.

Samples of the Grace-developed monolith catalyst have been supplied to Ford. At Ford's request, Grace also supplied monolith substrate samples to other catalyst manufacturers. Outside monolith suppliers being considered by Grace are American Lava and Corning; however, no commitments have been made to these companies. Grace doubts that American Lava could supply Grace's need (since they are under contract to Engelhard/Ford), unless American Lava would construct new facilities. In any event, the auto company would designate which monolithic substrate would be used.

Grace is negotiating with suppliers in South Africa and with the Soviet Union for potential noble metal needs. General Motors, however, would arrange directly with the metal supplier for its catalyst needs.

6.6 GULF OIL COMPANY

6.6.1 Company Experience and Products

6.6.1.1 Automotive and Nonautomotive Products

The Gulf Oil Company is a major refiner of petroleum products. In addition, Gulf is involved in a number of other ventures, including nuclear power, real estate, and hotel/motel developments.

The Process Research Division of Gulf is responsible for all research and development work conducted by Gulf in the area of petroleum processing (hydro-desulfurization, cracking, synthetic fuels, etc.). Approximately 90% of the efforts of this division are catalyst-oriented. All the catalysts used by Gulf are developed in-house and manufactured by outside companies under license to Gulf. Aside from petroleum products, Gulf does not supply products to the automotive industry.

6.6.1.2 Automotive Catalyst-Related products

Several years ago, Gulf decided to take a serious look at oxidation catalysts for automotive applications. However, this work, which had been initiated primarily to gain experience in the field of automotive catalysts and to advise the corporation on potential future gasoline requirements, has now been terminated.

More recently, a program has been started at Gulf to evaluate the problems related to the stringent 1976 NO_x standards and to determine whether Gulf's catalyst experience would be applicable to automotive reduction (NO_x) catalysts. It has since developed a number of reduction catalysts which look very promising in the laboratory. Samples of these catalysts have been submitted for testing to three major automobile manufacturers. In addition, Gulf has initiated an in-house reduction catalyst test program.

Gulf has investigated both monolithic and pellet substrates manufactured by several companies. Based on this work, Gulf has concluded that monoliths are the better choice for automotive applications. Although the monoliths supplied by American Lava (crystal structure) and Corning (extruded) have comparable physical properties, Gulf favors the extruded type, feeling that the extrusion process is less expensive and better for the noncylindrical catalyst configurations projected by some automobile and catalyst manufacturers.

With regard to pellet catalysts, Gulf has used primarily substrate material supplied by Kaiser. However, Gulf is now in the process of evaluating pellets from another manufacturer.

Gulf states that its reduction catalyst formulation consists of a number of different metals including a small amount of a "critical" element. However, it declines to identify the composition of the catalyst. Although Gulf would prefer to manufacture the catalysts in-house, it might also consider selling its catalyst formulation to other catalyst manufacturers.

Gulf will proceed with its reduction catalyst program until approximately December, 1972. If prospects remain promising, Gulf will then join with another company to investigate in more detail the problems and potential benefits associated with the design and operation of a reduction catalyst plant. Negotiations are presently under way with three or four manufacturers who have experience in mass production and good working relationships with the automobile industry.

6.6.1.3 Automotive Catalyst Test Programs

Performance and durability testing of Gulf reduction catalysts is being conducted by Gulf and a number of automobile manufacturers.

The test work at Gulf is primarily concerned with screening of catalysts and determination of basic performance parameters, including lightoff characteristics, lead and sulfur sensitivity, and ammonia formation. Also, Gulf is studying the mechanisms involved in NO_x reactions in an effort to find an explanation for the low ammonia formation observed on its catalysts.

A CFR (Cooperative Fuel Research Council) engine, two V-8 engines, and a complete CVS (Constant Volume Sampling) installation are available for this work.

Currently, Gulf has no plans for a catalyst/vehicle road test program. It feels that this work should be performed by the automobile manufacturers and not by the catalyst suppliers.

To date, Gulf has provided monolithic and pellet type reduction catalysts to a number of automobile manufacturers, including General Motors and Ford. The units delivered to General Motors for incorporation into the new General Motors Triple-Mode Emission Control System are six inches long and have a diameter of 3.28 inches. The catalysts supplied to Ford are three inches long and have a diameter of 4.6 inches.

General Motors has tested Gulf monolithic reduction catalysts on a Buick and a Cadillac vehicle between March and June of 1972 and has reported NO_x conversion efficiencies between 80% and 96%. One of these vehicles (using a Gulf reduction catalyst and a Grace oxidation catalyst) was tested by EPA in June 1972. The emissions from that vehicle were below the 1976 standards. In addition, General Motors has conducted a limited number of durability tests of Gulf pellet-type catalysts (Kaiser pellets).

6.6.2 Overall Schedule

Based on preliminary plant and process design studies, Gulf feels that approximately 18 months will be required for the design and construction of a reduction catalyst plant. The estimated lead time for the procurement of the plant equipment is six to eight months. Thus, a decision regarding the construction and operation of a manufacturing facility for reduction catalysts for 1976 model year vehicles is required before October 1973.

A "paper organization" is currently being set up by Gulf to handle the design, construction, and operation of such a catalyst plant. To date, Gulf has completed an in-house preliminary plant design study. The detail design work and the actual construction of the facility would be performed by an experienced outside contractor upon receipt by Gulf of a commitment from an automobile manufacturer. Gulf estimates that a capital investment of approximately $4 million is required for a catalyst plant designed for a capacity of 10 million units per year. A substantial part of the total cost will be spent on warehousing facilities. No decision has been made with respect to plant location. Although Gulf declines to identify its catalyzing process and the equipment used in its projected catalyst plant, it indicates that all process equipment is conventional in nature, and the processes involved in the production of automotive catalysts are apparently simple by petro-chemical standards. As a result, Gulf does not anticipate any major problems related to the construction and operation of a catalyst plant.

All plant construction material, process equipment, substrates and the raw materials required for the wash coat and the active metal coating will be procured from outside sources. Gulf has no in-house production capability in these areas.

6.6.3 Contractual Agreements

Gulf has not yet received commitments for reduction catalysts from the automobile industry. Since reduction catalysts are not utilized in 1975 model year vehicles, Gulf feels that serious reduction catalyst negotiations with the automobile manufacturers and potential substrate suppliers will not be initiated before August 1973.

Discussions are in progress with a number of firms to evaluate the prospects of a jointly owned catalyst manufacturing company.

6.7 KAISER ALUMINUM AND CHEMICAL CORPORATION

6.7.1 Company Experience and Products

6.7.1.1 Automotive and Nonautomotive Products

Kaiser is a major producer of aluminum products. In the early 1950's Kaiser entered the specialty aluminas field, with the production and sale of alumina hydrate and calcined alumina. The aluminas are marketed to major segments of industry for use in dehydration processes and the manufacture of many products, including abrasives, catalysts, ceramics, petrochemicals, and refractory materials. In addition, Kaiser has continued research, development, and facilities construction work related to the production of highly active and durable aluminas.

6.7.1.2 Automotive Catalyst-Related Products

Kaiser's experience in the area of aluminas is directly applicable to the manufacture of the substrates currently projected for use in automotive catalytic converter systems.

In 1959, Kaiser began commercial production of high-purity, low-cost spherical active alumina. Although this material was designed primarily for use as a dehydrating agent, certain of its properties proved to be useful to the catalyst industry. This was evident during the 1961 through 1962 time period when a specially modified alumina product was provided by Kaiser for potential use in the automotive catalysts considered by the State of California at that time.

In 1970, Kaiser began commercial production of gel-type alumina. This particular material was manufactured by means of a new process technique which is substantially different from that normally employed in the manufacture of active aluminas.

6.7.1.3 Automotive Catalyst/Substrate Test Programs

Since 1970, Kaiser has delivered pellet substrate material for test purposes to a total of 22 domestic and foreign automobile and catalyst manufacturers, including General Motors, Chrysler, Ford, Engelhard, and Matthey Bishop.

In-house testing by Kaiser is limited to the determination and evaluation of the physical properties of their product, including surface area, bulk density, porosity, crushing strength, and attrition.

6.7.1.4 Current Research Programs

Recently, Kaiser has terminated all its research and development work on substrate materials for automotive applications, because of its inability to obtain commitments from the automobile industry. Kaiser's development expenditures to date exceed $1 million.

6.7.2 Overall Schedule

6.7.2.1 Normal Production Lead Time Schedule

Kaiser has concluded that the construction of new plants would be required for the production of pellet substrates for automotive application, because of insufficient capacity of its Baton Rouge facility. The current schedule for its projected plant is presented in Figure 6-13. After receipt of a firm commitment, an initial period of one month is required to institute engineering services. Following that, a 20-month period is then needed for plant and process line construction and up to three months to achieve full production capacity.

The plant would be located somewhere other than Baton Rouge because that particular area is not considered by Kaiser to be economically desirable. The projected plant has a capacity of up to 60 million pounds per year of pellet substrate material which would be adequate to satisfy the requirements of all domestic automobile manufacturers.

6.7.2.2 Major Impact Factors

Kaiser feels that the longest lead time items in its schedule are the calciners and kilns. Both components require a lead time of approximately eight to ten months after completion of the engineering design.

The production of the alumina substrate involves problems related to water and air pollution. Kaiser feels that a considerable effort is required to solve these problems, and this could have a significant impact

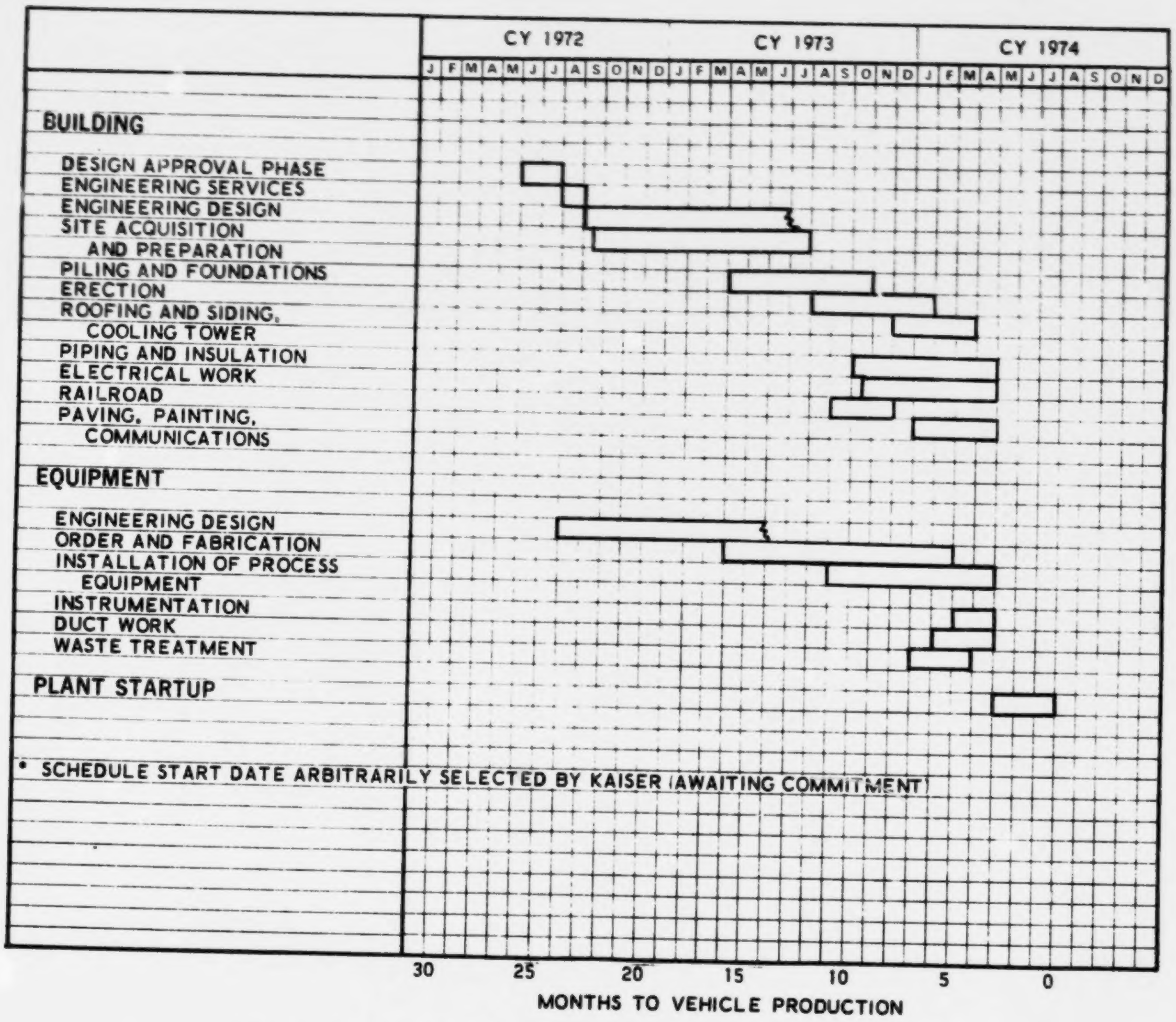


Figure 6-13. Kaiser Production Lead Time Schedule

on production lead time. Evaluation of these problems is not yet complete.

Relative to schedule compression, Kaiser states that no significant compression is possible for its projected new substrate plant. In Kaiser's opinion, overtime labor would not be the answer and would only result in higher cost. However, approximately 4 million pounds of pellet substrates could be provided prior to completion of its new plant by means of stockpiling substrates manufactured at Kaiser's existing Baton Rouge facility. In addition, the annual production capacity of the Baton Rouge plant could be increased by as much as four to five million pounds by incorporating additional equipment. However, Kaiser states that this would result in a cost increase of the substrate material.

6.7.3 Major Schedule Elements

6.7.3.1 Plant Design and Construction

After initial agreements have been reached with the catalyst and automobile manufacturers, a request for investment will be prepared by Kaiser for in-house corporate review and approval. Then a definitized agreement will be worked out with the catalyst manufacturer for inclusion in the final request for investment to Kaiser's board of directors. The total time period allotted for these negotiations is approximately one month, although considerably more time may actually be required.

Although not shown in the schedule (Figure 6-13), Kaiser will initiate work on a number of items to meet critical path scheduling. These include final process design, final piping and instrument diagrams, major process equipment and design, final plant layout design, final site preparation engineering, and preparation of waste disposal permit applications prior to final program approval by the Kaiser board of directors. The major portion of the design work would be completed approximately ten months after the project start date.

Upon receipt of the waste disposal permit, plant site preparation and foundation work commences. This work will be essentially completed approximately 15 months after project approval. Structural steel erection commences during the 13th month after project approval and requires six months to complete. Mechanical, electrical, instrumentation, and piping work starts during the 14th month after project approval, and will be completed in approximately seven months.

6.7.3.2 Equipment and Material Procurement

The long lead time process equipment items will be designed and ordered upon project approval by Kaiser's board of directors. Installation of this equipment is scheduled to commence approximately 13 months after program approval. The scheduled completion date for this phase is 21 months after project approval. As indicated in Figure 6-13, the electrical, instrumentation, and piping phases overlap with the major process equipment procurement and steel erection phases. With proper scheduling this overlap is feasible and, in fact, necessary in order to minimize the overall lead time requirements for the plant.

6.7.3.3 Plant Startup

Kaiser considers a period of three months necessary for the production line startup and plant shakedown and feels that this provides sufficient margin to implement production line equipment and process modifications, if required.

6.7.4 Pilot Plant

Currently, Kaiser's Baton Rouge plant has a maximum annual pellet substrate production capacity of approximately four million pounds. In the past, this plant has been used by Kaiser to optimize its substrate fabrication processes and to manufacture experimental substrate samples for use by the automotive industry. The pilot plant equipment is similar to the equipment considered for Kaiser's projected new plant.

6.7.5 Current and Pending Contractual Agreements

Kaiser has no commitments from the automotive industry for pellet substrates or raw alumina. It has submitted proposals to a number of potential automotive catalyst manufacturers covering substrate quantities of between 10 and 60 million pounds per year. Kaiser's latest proposal expired on August 31, 1972.

In lieu of a firm manufacturing proposal, Kaiser has recently submitted cancellable development proposals to a number of automobile/catalyst manufacturers. In this document, Kaiser proposes to start on the design of a substrate plant, with the customer paying cancellation costs in case of project termination.

6.8 MATTHEY BISHOP, INC.

6.8.1 Company Experience and Products

6.8.1.1 Automotive and Nonautomotive Products

Matthey Bishop, Inc. is an affiliate of Johnson Matthey Company, Inc., Wembley, England. Johnson Matthey is a major refiner of noble metals and a producer of catalysts for petrochemical applications. Other Johnson Matthey products include colors for the porcelain industry, rare-earths, and nonprecious metal tubing. It has a long-term (50 to 70 years) contract with Rustenburg Platinum Mines, Ltd. of South Africa to market the noble metals produced by that company. Currently, Matthey Bishop is involved in the reclamation of noble metals from spent catalysts for a number of petroleum products firms. In addition, it manufactures pellet catalysts for use as replacement material in catalytic exhaust purifiers installed on forklift trucks, and catalytic exhaust cleaners used in several paint spraying plants.

6.8.1.2 Automotive Catalyst-Related Products

Matthey Bishop is a manufacturer of experimental automotive oxidation and reduction catalysts. To date, several hundred oxidation catalysts and approximately 70 reduction catalysts have been supplied by Matthey Bishop to domestic automobile manufacturers, including Chrysler, Ford, International Harvester, and General Motors. Johnson Matthey and its affiliates have provided many additional catalysts to a number of European and Japanese automobile manufacturers. Most of the automotive catalysts manufactured by Matthey Bishop (and Johnson Matthey) to date are of the noble metal monolithic and noble metal/base metal monolithic types. In addition, a number of pellet-type catalyst configurations have been developed by Johnson Matthey for automotive applications. Since the performance of its pellet catalysts was generally lower than that of its monoliths, Matthey Bishop has decided to concentrate its catalyst development work on the monolithic type.

In order to provide the automobile manufacturers with a product of constant properties, Matthey Bishop has frozen its oxidation catalyst design some time ago. This monolithic catalyst, designated AEC-3A, contains approximately 0. 04 ounce of platinum and a proprietary amount of non-noble metals.

Matthey Bishop and Johnson Matthey are not interested in manufacturing substrates. They have evaluated substrates produced by a number of potential suppliers and have concluded that the American Lava and Corning monoliths are the best products currently available. Although Matthey Bishop feels that these substrates have a number of "nonideal" features (chipping, melting, etc.), it is confident that both firms will be able to further improve their products in the near future. Regardless of Matthey Bishop's evaluation of monolithic substrates it feels that the automobile manufacturers will make the final decision regarding the selection of the substrate supplier.

Matthey Bishop believes that the wash coat properties are at least as important as the catalyst formulation itself. It identified alumina as the major wash coat compound, but declined to identify the other six ingredients used in its formulation. Each one of these ingredients is being added to inhibit deactivation of the catalyst by one or more of the poisonous species contained in the engine exhaust gases. Generally, two suppliers will be selected by Matthey Bishop for each of the seven wash coat ingredients. With the exception of one compound, these ingredients are commodity items which are available in carload quantities.

Although Johnson Matthey has considerable experience in the design of catalyst canisters and packaging procedures, Matthey Bishop is not interested in becoming a canister manufacturer. Conversely, the European and Japanese affiliates of Johnson Matthey are directly involved in the design and production of the canister. Matthey Bishop feels that Chrysler, Ford and General Motors will manufacture their own containers and/or contract directly with outside suppliers. Conversely, International Harvester apparently perfers the procurement of packaged catalytic converters. In that case, Matthey Bishop would negotiate a contract for canisters with one of the leading domestic muffler manufacturers. However, to take full advantage of its own experience in that area, Matthey Bishop would participate in the design of the canister and the packaging procedures without cost to the canister manufacturer.

With regard to noble metal procurement, Matthey Bishop states that the noble metals would be supplied either by Johnson Matthey or by means of direct agreements between the automobile manufacturers and the noble metal mining firms.

6.8.1.3 Automotive Catalyst Test Programs

Performance and durability testing of Matthey Bishop/Johnson Matthey oxidation and reduction catalysts is being conducted by Matthey Bishop/Johnson Matthey and by a number of domestic and foreign automobile manufacturers.

The test work at Matthey Bishop is primarily concerned with screening of substrates and wash coat and catalyst formulations to determine and optimize their performance in terms of crushing strength, shrinkage, porosity, density, active metal loading, lightoff temperature and conversion efficiency. In addition, Matthey Bishop is conducting catalyst tests on a Chevrolet engine, a Ford engine, and a Buick vehicle. The Avenger vehicle, which had accumulated 24,000 miles at the time of the April 1972 EPA Suspension Request Hearings, exceeded the HC and CO standards at 26,500 miles. At that point, substrate cracking was observed (4-cylinder engine vibrations are still a serious problem) and the baseline emissions of the engine had increased considerably due to deposit buildup on the valves and the valve seats. The engine has since been overhauled and a new catalyst has been installed on the vehicle for further durability testing by Johnson Matthey. Other vehicle tests currently being conducted by Johnson Matthey include 1975 system concept tests on a Fury III and 1976 system concept tests on another vehicle.

6.8.1.4 Current Research Programs

Research and development work on advanced catalysts is proceeding at both Johnson Matthey and Matthey Bishop. These efforts are aimed primarily at reducing the platinum content of the AEC-3A catalyst and at discovering other suitable metals and combinations of metals. Also, new catalyst substrate designs (in terms of diameter and length) are being investigated. Matthey Bishop feels that most of the current catalysts are too short and that the catalyst design should be based on space velocity (approximately 100,000) and temperature considerations.

In addition, Matthey Bishop and Johnson Matthey are investigating all-base metal catalysts and monolithic reduction catalysts.

6.8.1.5 Noble Metal Reclamation

Matthey Bishop states that recovery of noble metals from spent automotive catalysts might not be economically feasible because of the many steps involved in such a program, including collection and shipment of the old catalysts to the refining plant and the costly smelting and refining processes required to achieve adequate noble metal purity.

6.8.2 Overall Schedule

6.8.2.1 Normal Production Lead Time Schedule

The lead time chart for the projected Matthey Bishop catalyst plant is shown in Figure 6-14. As indicated in this figure, Matthey Bishop requires a total of 20 months to complete the design, construction, equipment procurement, and startup/shakedown phases of the plant. No major problems related to plant construction and operation are currently foreseen by Matthey Bishop. The processes involved in manufacturing catalysts are considered simple by industry standards and the equipment required is conventional and of the type currently used by the chemical process industry. Matthey Bishop is very confident of its ability to build a catalyst plant in accordance with its lead time schedule and feels that the experience gained during the construction of its platinum refining plant (which required 18 months) is directly applicable to the projected automotive catalyst plant.

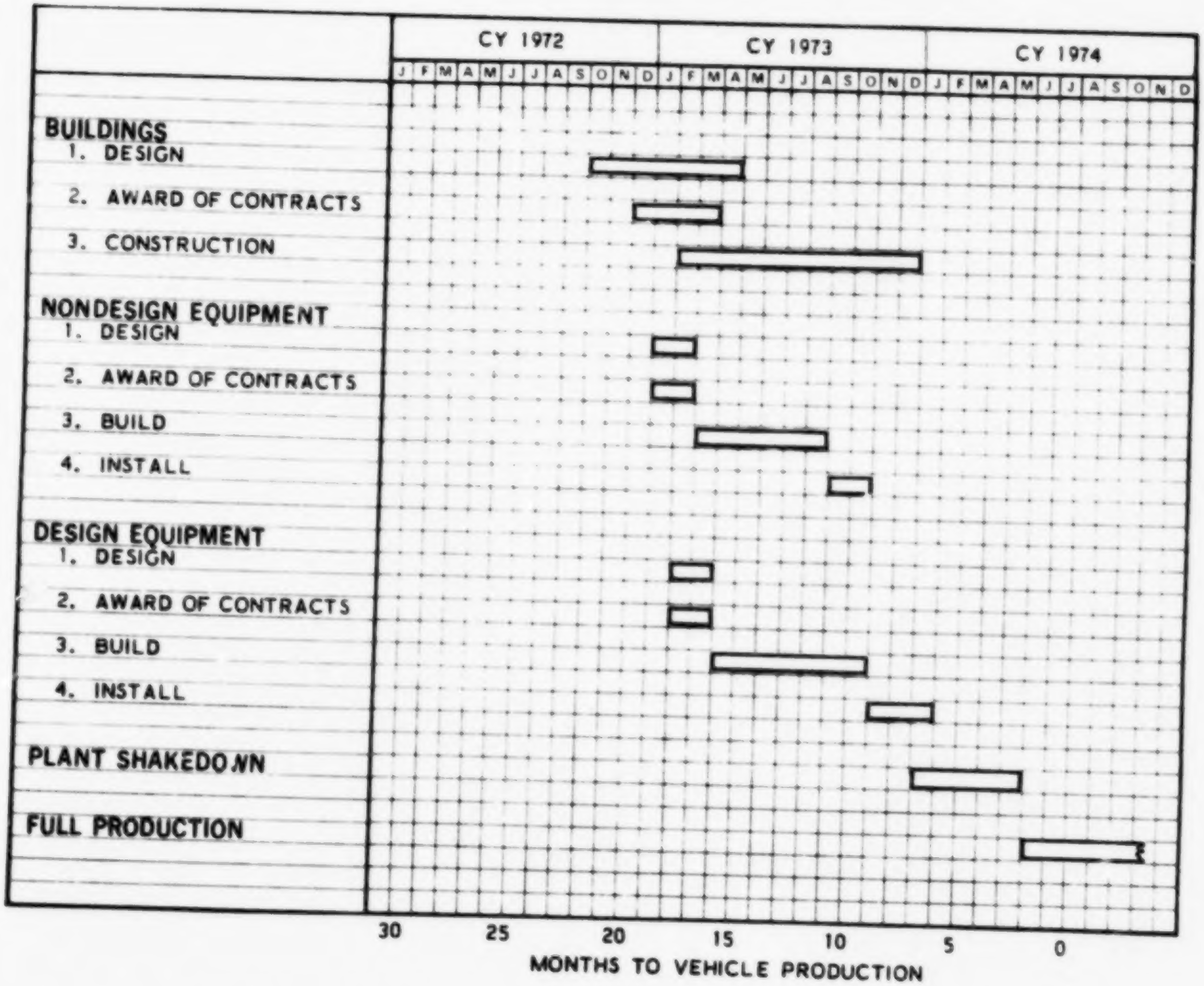


Figure 6-14. Matthey Bishop Production Lead Time Schedule

In order to minimize cost, Matthey Bishop has adopted a modular plant design concept. Initially, two identical production line modules are being considered by Matthey Bishop for the production of monolithic oxidation catalysts for Ford. As discussed in Section 6.8.6, Matthey Bishop feels that it will receive an order from Ford covering 30% of Ford's total 1975-1977 oxidation catalyst requirement. Each of the two production line modules will be designed for a nominal capacity (two 8-hour shifts, fifty 5-day work weeks) of 900,000 catalysts per year. By operating on a 3-shift, 7-day work week, the capacity of the two modules could be easily increased to supply approximately 50% of Ford's total requirement. Further expansion in plant capacity would require installation of additional production line modules. Since plant expansion is rather simple, a decision regarding additional capacity for oxidation catalysts can be delayed until approximately April 1973. However, orders for substrates might have to be placed before that date.

The floor space of the currently projected plant (2 modules) is approximately 50,000 square feet, most of which is used for warehousing and offices. The actual production area of each module covers approximately 2000-2500 square feet. Probably, the plant would be built adjacent to Matthey Bishop's new platinum refining plant located in Winslow, New Jersey.

According to Matthey Bishop, construction of its projected catalyst plant requires a capital investment of about $4 million. If a suitable building could be leased, the initial plant cost could be reduced by approximately $500,000. Although Matthey Bishop favors the construction of a new facility, it feels that a building might have to be leased unless a commitment from an automobile manufacturer is received before December 1, 1972.

6.8.2.2 Major Impact Factors

As indicated in Figure 6-14, the originally scheduled start date for Matthey Bishop's catalyst plant project was October 1, 1972. Initiation of the work on the plant project is being delayed until a commitment is received from an automobile manufacturer. However, Matthey Bishop feels that compression of the building phase of the schedule by approximately one to two months might be possible by means of overtime work. The cost increase due to schedule compression is considered negligible by Matthey Bishop.

According to Matthey Bishop a one-month compression of the nondesign equipment phase of the schedule might be feasible up to June 1973. The nondesign equipment consisting of basic process equipment (compressors, mixers, conveyors, instrumentation, etc.) can be ordered without knowing the precise monolith specification. Conversely, procurement of the design equipment (calciners, dryers, feeders) requires knowledge of the exact catalyst specifications and dimensions.

Since research and development work on improved catalysts is proceeding at Matthey Bishop, it is conceivable that improved wash coat and catalyst formulations will be available for use in the 1975 emission control systems. As long as platinum remains the major active compound of the catalyst formulation (base metals used as fillers), the currently projected catalyzing process and process equipment can be easily modified to accommodate new catalyst formulations. Also, substrate modifications in terms of length, shape, and cell structure can be implemented during the next six to eight months. Conversely, utilization of all-base metal formulations would probably require different process equipment and this might have a significant impact on production lead time. However, as previously stated, the prospects for all-base metal catalysts are not very bright at this time.

Production volume currently has little effect on lead time because of the modular design concept used by Matthey Bishop in the construction of its plant. Also, the catalyst durability requirement (currently 50,000 miles) has little impact on lead time unless the required catalyst life would be reduced to the 10,000 mile level. In that case, pelletized palladium catalysts might be applicable, and this might simplify the catalyst manufacturing process.

6.8.2.3 Reduction Catalysts

As previously pointed out, Matthey Bishop is working on the development of automotive reduction catalysts. It appears that the equipment required for the manufacture of reduction catalysts is similar to that used by

Matthey Bishop in its projected oxidation catalyst plant. Therefore, reduction catalysts could also be manufactured in its projected plant, although installation of additional production line modules might be required. Since reduction catalysts are not utilized in 1975 emission control systems, no decisions are required in the near future regarding construction of production facilities for reduction catalysts.

6.8.3 Major Schedule Elements

6.8.3.1 Plant Design and Construction

As indicated in Matthey Bishop's production lead time schedule (Figure 6-14), the plant design and construction phase extends over a period of 15 months. The building design phase has been under way for some time. Preliminary plant design, process design, and schedule analyses have been completed by Matthey Bishop, including sizing of the required plant equipment. The preliminary plant design and project schedule work conducted by Matthey Bishop is currently being refined and detailed by an outside engineering firm, without cost to Matthey Bishop. The firm selected by Matthey Bishop for this work has extensive experience in mass production procedures and processes. Upon receipt by Matthey Bishop of a commitment for catalysts, this firm will be awarded a turnkey contract for the projected catalyst plant. The plant will be constructed adjacent to Matthey Bishop's platinum refining plant located in Winslow, New Jersey.

6.8.3.2 Equipment and Material Procurement

The equipment required by Matthey Bishop for its projected catalyst plant is conventional in nature and of the type currently used by the petrochemical process industry. Procurement of the nondesign equipment requires approximately 11 months. This equipment includes storage and mixing tanks for the wash coat and active catalyst solution, pipes, conveyors, blowers, pumps, instrumentation, purge gases, waste treatment equipment and warehousing facilities. Since Matthey Bishop's catalyst manufacturing process does not involve utilization of chloroplatinic acid, the problems associated with the treatment of the off-gases are alleviated, compared with the catalyzing processes used by other catalyst manufacturers.

The estimated lead time required for the design, fabrication, and installation of the design equipment is 12 months. This equipment includes calciners, dryers, feeders and other components required in the application process of the wash coat and catalyst formulations. The dryers, which are approximately 100 feet long, represent the most expensive single item.

Most of the instrumentation required is quality-control-type equipment. The most sophisticated instrument is a spectrographic device (manufactured by Norelco) which will be used on-line to measure the overall platinum loading of the catalysts. Procurement of this instrument requires approximately five to six months. Other critical components include the calciners and dryers which have a total lead time of approximately nine months. Assembly of the production line will be handled by a special contractor who has experience in the area of production line design and installation.

Matthey Bishop is not interested in the manufacture of substrates, canisters, and wash coat and catalyst compounds. American Lava and Corning are considered potential monolithic substrate suppliers. In the past, Matthey Bishop has been told by the substrate manufacturers that sufficient substrates would be made available to Matthey Bishop either directly or through the automobile manufacturers.

For PTX-5 type (round) monolithic substrates, American Lava provided Matthey Bishop with a cost quote of $2.81 per unit. The cost of the equivalent Corning product is $2.54. For oval designs, the projected cost of the American Lava substrate is almost twice that of the Corning substrate. Although most of the automobile manufacturers prefer round catalysts, Matthey Bishop feels that oval configurations might be a better choice. A price of $15 - $18 was quoted by Matthey Bishop for its finished product, including the substrate, wash coat, and noble metal coating. All these cost data are based on high volume production.

The wash coat ingredients used by Matthey Bishop are commodity items, except for one compound which requires a lead time of approximately 6 months. This particular product will be used at the rate of 5000 pounds per month. Both American Lava and Corning have also shown interest in the wash coat business. However, Matthey Bishop feels that its own wash coat technology is more advanced than that of other companies.

The noble metal required by Matthey Bishop in its catalyst formulation will be procured either by Matthey Bishop or by the automobile manufacturers themselves. According to Johnson Matthey, adequate supplies of platinum and other noble metals will be available in 1975 for use in automotive catalysts. The question of platinum availability and usage is discussed in more detail in Section 11.

6.8.3.3 Plant Startup

Matthey Bishop considers that a five month period is desirable for plant startup and shakedown. During that period, approximately 45 people will be hired and trained to operate the catalyst plant. Based on this schedule the plant will be fully operational by June 1, 1974.

6.8.4 Quality Control and Warranty

Matthey Bishop feels that quality control might be a potential problem area. To assure adequate product performance, continuous on-line tests as well as batch tests will be performed by Matthey Bishop. These tests are listed in Table 6-6. The thickness distribution of the wash coat and active metal layer will be determined by means of destructive tests not listed in the table.

Matthey Bishop will only guarantee its product in terms of meeting the specifications established jointly by the customer (automobile manufacturer) and Matthey Bishop. It will not guarantee the substrate, the canister, and the performance of the catalyst in the vehicle.

6.8.5 Pilot Plant

Johnson Matthey has been operating a nonautomated catalyst pilot plant in England for some time. This plant has a production capacity of approximately 100 catalysts per day and is used by Johnson Matthey to manufacture catalysts required by the European automobile industry for test purposes.

Table 6-6. Matthey Bishop Quality Control Tests

Test/Property Identification	Test Type(1)
Average particle size - dry - wash coat	B
Particle distribution - wash coat	B
Spectrographic analysis - wash coat	B
Dissolved solids - wash coat	B
Specific gravity - wash coat	B
Viscosity - wash coat	B
pH-control - wash coat	C
Visual inspection - substrate	C
Average water absorption - substrate	B
Spectrographic analysis - substrate	B
Surface area after wash coating	B
Elemental purity - PGM(2) raw material	B
Compositional analysis - PGM(2) input	B
PGM(2) concentration - catalyst solution	B
Qualitative PGM(2) presence - catalyst	C
PGM(2) loading and uniformity - catalyst	B
PGM(2) surface area - catalyst	B
Analysis - raw materials	B

(1) B = Batch
C = Continuous

(2) PGM - Platinum Group Metals

Matthey Bishop is in the process of constructing an automated pilot plant in the United States. This plant is designed for a maximum capacity of 700 units per day and will be completed in December 1972. The plant can be scaled up and will be used primarily to optimize catalyst manufacturing processes and to fabricate experimental catalysts for use by the automobile industry and by Matthey Bishop.

6.8.6 Current and Pending Contractual Agreements

Contract negotiations with Ford have been under way since the beginning of August 1972 and Matthey Bishop expects a firm commitment for catalysts from Ford. As an alternate approach, Ford has recently proposed to form a jointly owned catalyst company with Matthey Bishop. Most likely the commitment from Ford will be for 30% of Ford's total catalyst requirement for three years, and will amount to approximately 1.8 million units per year. Previously, Engelhard has been awarded 60 percent of the Ford catalyst business and, according to Matthey Bishop, the remaining 10 percent might be produced by Ford themselves.

Recently, contract negotiations have been initiated with Chrysler also. Matthey Bishop believes that its share might be as much as 25 to 30% of Chrysler's total catalyst requirement. Also, Matthey Bishop might be asked by International Harvester to supply all the catalysts required by that company. Conversely, it expects no orders from General Motors and from American Motors.

To date, no contracts have been awarded by Matthey Bishop to substrate and materials suppliers. It has an agreement in principle with an engineering firm for the construction of the catalyst plant. Contracts for substrates will be negotiated with American Lava and/or Corning upon completion of the Ford/Matthey Bishop contract negotiations.

6.9 MONSANTO COMPANY

6.9.1 Company Experience and Products

6.9.1.1 Automotive and Nonautomotive Products

Monsanto is a major producer of chemical products, including plastics, resins, man-made fibers, herbicides, detergents, and petroleum products, with facilities in the United States, Europe, South America and Asia. In addition, a number of finished products are being marketed by Monsanto including household items and electronic and process control equipment. Enviro-Chem Systems, Inc., a wholly owned subsidiary is active in the area of air and water pollution and solid waste abatement.

Currently, Monsanto supplies the domestic and European automotive industry with a number of products including chemicals and nylon yarn used by tire manufacturers, polyvinyl butyral (PUB) sheets used as interlayers in safety glass, and allyl alcohol for use in a newly developed auto body priming process in Europe.

6.9.1.2 Automotive Catalyst-Related Products

Monsanto has manufactured a number of pellet type, base metal and promoted base metal catalysts for automotive applications. Originally all-base metal formulations were utilized by Monsanto. However, more recently, it has initiated development of promoted formulations which contain a proprietary amount of noble metal to improve the lightoff and durability characteristics of the catalyst. Monsanto declines to identify the type and amount of noble metal used in its new catalyst formulations.

To date, Monsanto has submitted pellet-type base metal oxidation catalyst samples to almost all automobile manufacturers with the exception of British and German firms. Although it has not been encouraged by Ford as far as base metal pellet type catalysts are concerned, it is concentrating its efforts on pellets since it is not interested in manufacturing another catalyst of the Engelhard PTX type.

A number of pellet type reduction catalysts are also being developed by Monsanto. However, these catalysts which have shown good performance under idealized conditions in the laboratory are currently not ready for installation in vehicles.

Monsanto has no plans to manufacture catalyst substrates, wash coat materials, or canisters. Most likely, the substrate and the alumina used in the wash coat would be purchased from Kaiser, Reynolds, Pechiney or other suppliers. Monsanto states that the production of the catalyst canisters will probably be handled by the automobile manufacturers themselves.

6.9.1.3 Automotive Catalyst Test Programs

Performance and durability tests of Monsanto pellet type oxidation catalysts are being conducted by Monsanto and by a number of automobile manufacturers, including General Motors, Saab and Volvo.

The test programs performed by Monsanto include cold start simulation (COSIM) tests on the dynamometer, special engine dynamometer tests designed to simulate the thermal loads on the catalyst during vehicle operation, and accelerated mileage accumulation tests. The COSIM procedure, developed by Monsanto, is less complicated than the CVS procedure and is used by Monsanto in most of its emission test work. Catalyst durability tests are conducted in accordance with its own special accelerated test procedure. In that procedure controlled amounts of fuel contaminants are used and the catalyst is exposed to temperatures above and below those normally encountered in vehicle certification and AMA driving cycle testing. As a result, performance trends are detected much sooner than by means of conventional procedures.

Catalyst testing in 1972 General Motors vehicles are being conducted by Auto Labs, Denver, Colorado, under contract to Monsanto. The purpose of these tests is to identify the best catalysts in terms of lightoff characteristics and durability in the vehicle. General Motors also is testing Monsanto's pellet catalysts. One of these promoted base metal designs has successfully accumulated the equivalent of 23,000 miles. Saab has tested a number of Monsanto catalysts in Saab vehicles. One of these vehicles incorporating an "advanced" Monsanto catalyst (probably promoted base metal) has accumulated 27,000 miles within the 1975 Federal emission standards. However, the same catalyst type has failed for unknown reasons in another Saab vehicle and also at General Motors.

6.9.1.4 Current Research Programs

Monsanto is continuing research and development work on automotive pellet type oxidation and reduction catalysts using base metal and promoted base metal formulations. These efforts are aimed at improved catalyst performance in terms of lightoff temperature, durability and sensitivity to poisonous fuel contaminants, such as lead, sulfur and phosphorus.

6.9.2 Overall Schedule

6.9.2.1 Normal Production Lead Time Schedule

A chart showing the functional steps for construction of Monsanto's automotive catalyst plant is presented in Figure 6-15. Additional information is included in its ECA oxidation catalyst production lead time schedule, illustrated in Figure 6-16. This schedule is identical to that previously provided by Monsanto to all its potential customers and to EPA. As indicated in this schedule, a total lead time of 24 months is projected for the construction and startup of a pellet catalyst plant.

According to Monsanto, the schedule in Figure 6-16 is already accelerated for the first nine months and is "normal" thereafter. As indicated, the initial study efforts by both Monsanto and its substrate supplier(s) commence well in advance of the completion of contract negotiations and appropriation request approval by Monsanto's top management.

Monsanto states that construction of a new plant would be required since no existing Monsanto facility is available that could be modified for catalyst production. Part of the preliminary plant and process engineering and economics has been completed by Monsanto. The plant would be designed for a pellet catalyst capacity of 10 to 50 million pounds per year, which is sufficient for approximately 2 to 10 million converters. Monsanto considers construction of a plant of this type to be a major undertaking.

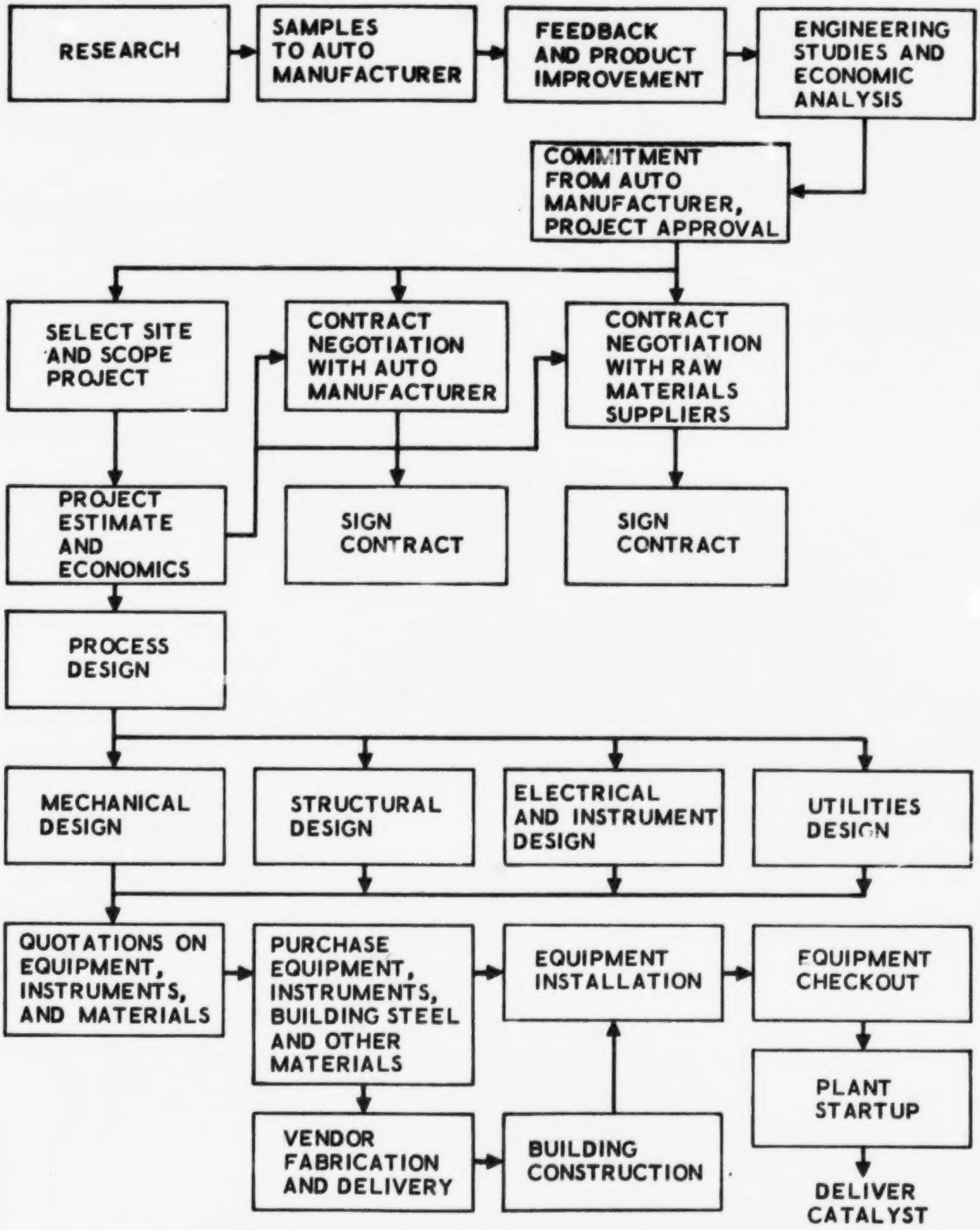
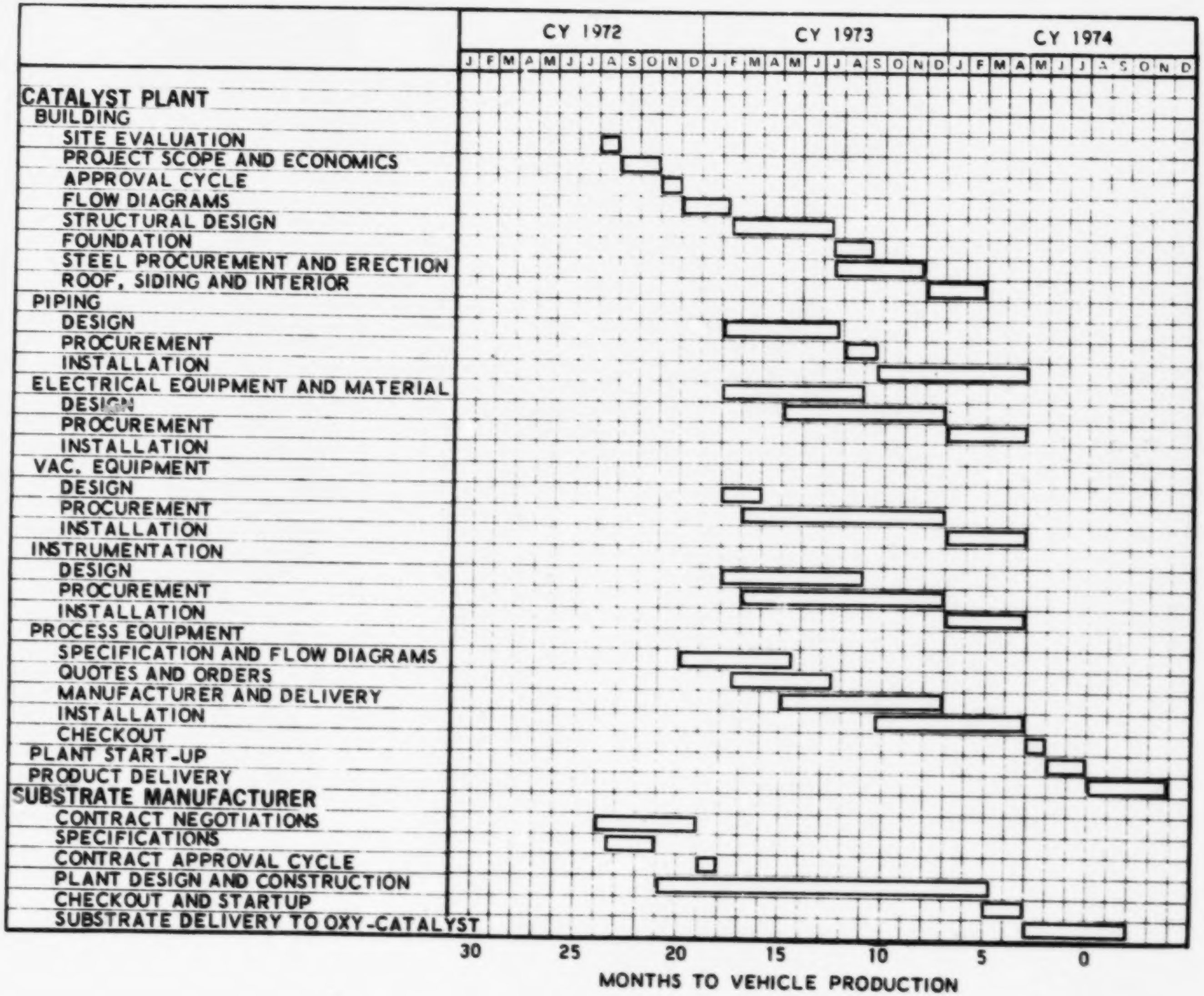

RESEARCH
SAMPLES TO AUTO MANUFACTURER
FEEDBACK AND PRODUCT IMPROVEMENT
ENGINEERING STUDIES AND ECONOMIC ANALYSIS
COMMITMENT FROM AUTO MANUFACTURER, PROJECT APPROVAL
SELECT SITE AND SCOPE PROJECT
CONTRACT NEGOTIATION WITH AUTO MANUFACTURER
CONTRACT NEGOTIATION WITH RAW MATERIALS SUPPLIERS
PROJECT ESTIMATE AND ECONOMICS
SIGN CONTRACT
SIGN CONTRACT
PROCESS DESIGN
MECHANICAL DESIGN
STRUCTURAL DESIGN
ELECTRICAL AND INSTRUMENT DESIGN
UTILITIES DESIGN
QUOTATIONS ON EQUIPMENT, INSTRUMENTS, AND MATERIALS
PURCHASE EQUIPMENT, INSTRUMENTS, BUILDING STEEL AND OTHER MATERIALS
EQUIPMENT INSTALLATION
EQUIPMENT CHECKOUT
VENDOR FABRICATION AND DELIVERY
BUILDING CONSTRUCTION
PLANT STARTUP
DELIVER CATALYST

Figure 6-15. Monsanto Functional Step Chart--Automotive Exhaust Catalyst Project



* SCHEDULE END DATE ARBITRARILY SELECTED

Figure 6-16. Monsanto Production Lead Time Schedule* (ECA Oxidation Catalyst Plant)

The total estimated plant expenditure is of the order of several million dollars.

Monsanto emphasizes that it would never build a catalyst plant without a firm long range commitment from an automobile manufacturer. In justifying its position Monsanto states that a catalyst plant is designed specifically for catalyst production, and conversion of such a plant to another product line is unfeasible. Conversely, it feels that plants designed for the fabrication of conventional automotive parts, such as frames, are more flexible and can be easily modified to produce other components.

Monsanto believes that the construction and operation of its projected pellet catalyst facility is simple by comparison with most of its chemical process plants. Although neither Monsanto nor its potential substrate and equipment suppliers expect any problems in the construction and operation of a pellet catalyst plant, it states that delays could occur, of course, as a result of strikes and other unpredictable events.

6.9.2.2 Major Impact Factors

Monsanto states that the assembly of the catalyst production line and procurement of the substrate material are the most critical items in its schedule. As indicated in Figure 6-16, a total of 20 months is required for the equipment specifications, plant and process design, component procurement, installation, checkout, and startup of the catalyst production line. Based on information received by Monsanto from potential substrate suppliers, the lead time for the design, construction, checkout, and startup of the substrate plant is 18 months. This does not include the three-month initial time period required for contract negotiations and establishment of product specifications.

Monsanto does not foresee any lead time problems related to the procurement of the catalyst plant equipment. This equipment, which is itemized in Section 6.9.3.2, is conventional in nature and of the type currently used by the chemical process industry. The critical equipment components are the calciners, dryers, and coolers, which require a lead time of five to eight months.

With regard to further compression of its schedule (Figure 6-16), Monsanto feels that some additional reduction in lead time might be possible by means of overtime work on the part of the plant construction and equipment supply firms. However, the magnitude of schedule compression and the associated cost increase cannot be estimated by Monsanto at this time.

Improvements in catalyst formulation can be implemented almost up to the completion date of plant construction. However, substrate and catalyst modifications requiring different process equipment probably could not be incorporated after placement of the equipment orders. Monsanto feels that the capacity of its projected catalyst plant could be increased very easily by increasing the number of production line modules providing sufficient power will be available from the utilities. A decision regarding additional plant capacity would be required approximately nine months after the go-ahead date of the catalyst plant project.

6.9.2.3 Reduction Catalysts

Although research and development on reduction catalysts has been under way at Monsanto for some time, Monsanto feels that these catalysts are not yet ready for production. Therefore, it has no current plans for construction of a reduction catalyst plant. However, it feels that the manufacturing processes and the required production line equipment are very similar to those used in its projected pellet oxidation catalyst plant.

6.9.3 Major Schedule Elements

6.9.3.1 Plant Design and Construction

To date, Monsanto has completed the first four items listed on its functional step chart (Figure 6-15). However, further work on the project has been suspended until a firm commitment for catalysts has been received from an automobile manufacturer.

The plant and process design work would be performed in-house, utilizing Monsanto's expertise in that area. It has a sizable plant design department which is responsible for all its plant and process engineering and construction work.

As indicated in Figure 6-15, the actual plant construction work commences with the site evaluation and process basis phases. The site evaluation phase is concerned with the final selection of the plant location and considers such factors as location of the automobile manufacturing plant, freight rates, weather conditions during plant construction, etc. The process basis phase is concerned with final considerations and decisions regarding final selection of the product and the manufacturing procedures. During the project scope phase, a document will be prepared by Monsanto presenting guidelines for the operation of the plant. Following project approval by Monsanto management, all plant equipment and materials will be designed and ordered. Plant erection commences upon delivery of the foundation material and structural steel.

6.9.3.2 Equipment and Material Procurement

The equipment materials identified by Monsanto for its projected catalyst plant are listed in Table 6-7. The delivery times shown in this table are referenced to the date of purchase order.

Table 6-7. Monsanto Projected Equipment and Material Lead Time Requirements

Equipment/Material	Projected Lead Time in Months	Equipment/Material	Projected Lead Time in Months
Structural Steel	3 to 4	Dryers, Calciners, Coolers	5 to 8
Pipes, Valves, Fittings	1	Storage Bins and Silos	3 to 4
Electrical Substations	4 to 6	Pumps	3 to 4
Other Electrical Equipment	2 to 3	Tanks	3 to 4
Process Instrumentation	2 to 3	Noble Metal	18
Conveying Equipment	3 to 4	Dust collection equipment	Not identified
Screens	2	Waste disposal equipment	Not identified

All these components are conventional items of the type currently used by Monsanto and other chemical process companies, except perhaps for the projected dust collection and waste disposal equipment. However, no problems are anticipated regarding the procurement of the pollution abatement systems. As indicated, the critical items are dryers, calciners, and coolers, which require a procurement time of five to eight months. All plant equipment and materials will be procured from outside sources since Monsanto has no facilities to manufacture components of this type.

Currently, Monsanto does not intend to produce the catalyst substrates and the raw materials required for the wash coat and the active metal layer of the catalyst. Kaiser and Reynolds are considered potential substrate suppliers. The wash coat ingredients are commodity items and no difficulties are anticipated in the procurement of these materials. The noble metal required for Monsanto's newly developed promoted base metal catalyst formulations would be procured either by the auto manufacturers themselves or through direct negotiations by Monsanto with noble metal producers. Apparently, Monsanto, through its European operations, has good business relations with the Soviet Union and would prefer to deal directly with the Russians in this matter. Monsanto has requested permission from the State Department to investigate a noble metal deal with the Soviet Union.

According to Monsanto, catalyst substrate suppliers require a lead time of 21 months from initiation of contract negotiations. As indicated in Figure 6-16, a period of 18 months is required for the actual design, procurement, construction, and production startup phases of the substrate plant. These time periods are in reasonable agreement with the lead time requirements quoted by Reynolds (18 months) and by Oxy-Catalyst for substrate delivered to Oxy-Catalyst by Kaiser (21 months) and by Reynolds (21 months), and are compatible with the lead times required for Monsanto's catalyst plant and for noble metal procurement.

6.9.3.3 Plant Startup

No unusual problems are anticipated by Monsanto with respect to the startup and shakedown of its projected catalyst plant. Based on past experience with chemical process plants, Monsanto feels that a 3 month period is adequate for checkout and startup of a catalyst plant.

6.9.4 Quality Control and Warranty

Although sophisticated quality control procedures will be required in the manufacture of catalysts, Monsanto expects no unusual problems related to quality control. Monsanto has developed proprietary test procedures including on-line monitoring and batch test methods to determine a multiplicity of substrate and catalyst performance parameters (i.e., substrate crushing strength, porosity, shrinkage at elevated temperatures, catalyst activity, etc.).

With regard to warranty, Monsanto states that its catalysts will be guaranteed to meet the specifications established jointly by Monsanto and the customer. Also, Monsanto will guarantee the performance of the catalyst when determined in accordance with its test procedures. However, catalyst performance in the vehicle cannot be guaranteed by Monsanto because of interactions between the catalyst and other emission control system components.

6.9.5 Pilot Plant

Construction of a catalyst pilot plant has been given some consideration by Monsanto. It has concluded that a pilot plant would require less lead time and capital investment than a full-size plant. However, the product cost would be higher compared with a full-size plant and the production capacity would not be sufficient to supply more than a small fraction of the catalysts required by a major automobile manufacturer. A decision regarding the construction of a pilot plant will be made by Monsanto upon receipt of a commitment from an automobile manufacturer.

Currently, all Monsanto catalysts are manufactured in its low-capacity batch process facility.

6.9.6 Current and Pending Contractual Agreements

Although Monsanto has provided General Motors with many experimental base metal pellet type catalysts, it has no commitment for catalysts from General Motors or from any other automobile manufacturer. Currently, Monsanto has no contractual agreements with potential suppliers of plant equipment and catalyst raw materials.

6.10 OXY-CATALYST, INC.

6.10.1 Company Experience and Products

6.10.1.1 Automotive and Nonautomotive Products

Oxy-Catalyst, Inc., a subsidiary of Research-Cottrell, Inc., is a principal manufacturer of catalytic exhaust purifiers used in spark ignition engine and diesel engine powered industrial vehicles (forklift trucks, mine locomotives, etc.). To date, Oxy-Catalyst has manufactured approximately 90% of the pellet (bead) type catalysts procured by industry for these applications. Monolithic (rod-type) catalysts for use in forklift trucks are also being produced and marketed by Oxy-Catalyst. Other products manufactured by Oxy-Catalyst include small catalytic units used by the airlines to eliminate kitchen odors, and large industrial catalytic exhaust gas treatment systems containing several cubic feet of pellet catalyst material.

6.10.1.2 Automotive Catalyst-Related Products

For automotive applications, Oxy-Catalyst is considering the manufacture of both pellet and monolithic (honeycomb) type catalysts utilizing base metal, noble metal, and promoted base metal formulations. Its promoted base metal catalysts contain small amounts (0.01 to 0.04 ounce) of noble metals. Currently, it favors the pellet type, primarily for product cost and replacement reasons. The issue of catalyst replacement is discussed in Section 6.10.1.5.

Currently Oxy-Catalyst is concentrating its automotive catalyst development efforts in the area of promoted base metal configurations. In these formulations the noble metal (primarily platinum) is being added primarily to increase catalyst durability. Oxy-Catalyst quotes a price of approximately $10 for its promoted catalyst (five to six pounds of pellet catalyst required per catalytic converter), and about $6 for all-base metal designs. These costs are low compared with the cost of $40 to $50 for its monolithic (platinum) catalysts.

Oxy-Catalyst has no intention of manufacturing the catalyst substrates and the ingredients required for the wash coat and the active layer of the catalyst. These materials will be procured from outside sources.

Although Oxy-Catalyst manufactures the converter package for their forklift truck units (including canister and containment screens), it has no plans to fabricate canisters for automotive catalysts.

6.10.1.3 Automotive Catalyst Test Programs

The test work performed by Oxy-Catalyst is primarily concerned with preliminary screening of its catalysts in bench test setups. These tests are conducted to determine catalyst activity, shrinkage at elevated temperatures, attrition and abrasion characteristics, crushing strength, and thermal and chemical stability. Oxy-Catalyst does not perform catalyst performance tests on vehicles, and therefore has to rely on data supplied by the automobile manufacturers.

To date, more than 100 different oxidation catalyst configurations have been submitted by Oxy-Catalyst to a number of automobile manufacturers, including General Motors, Ford, Chrysler, and several European and Japanese companies. The majority of these catalysts are of the base metal, pellet type.

6.10.1.4 Current Research Programs

Research work on base metal, noble metal, and promoted base metal oxidation catalysts is proceeding at Oxy-Catalyst. These efforts are aimed at the development of improved catalyst configurations, in terms of lightoff temperature, HC/CO conversion efficiency and durability. Both pellet and monolithic designs are being evaluated.

In the area of reduction (NO_x) catalysts, research and development work is being conducted on metallic monolith type configurations. One of these catalysts has been tested by General Motors. Although the performance of this catalyst was satisfactory, further engineering work is required on the metallic substrate design concept.

6.10.1.5 Catalyst Replacement and Noble Metal Recovery

Since catalysts may not be capable of meeting the 50,000-mile durability requirement, the question of catalyst replacement is considered a very important issue by Oxy-Catalyst. It has developed a reliable and simple replacement method for pellet catalysts which is widely used on its fork-lift truck units. The equipment required to replace the catalyst pellets consists of a vibrator/vacuum device which is being marketed by Oxy-Catalyst, (Oxy-Quik Catalyst Changer). According to Oxy-Catalyst, the pellet replacement cost is approximately $20 to $30 per catalyst. Conversely, Oxy-Catalyst states that the projected replacement cost for monolithic catalysts is considerably higher, because of the required exchange of complete converter units (catalyst and container).

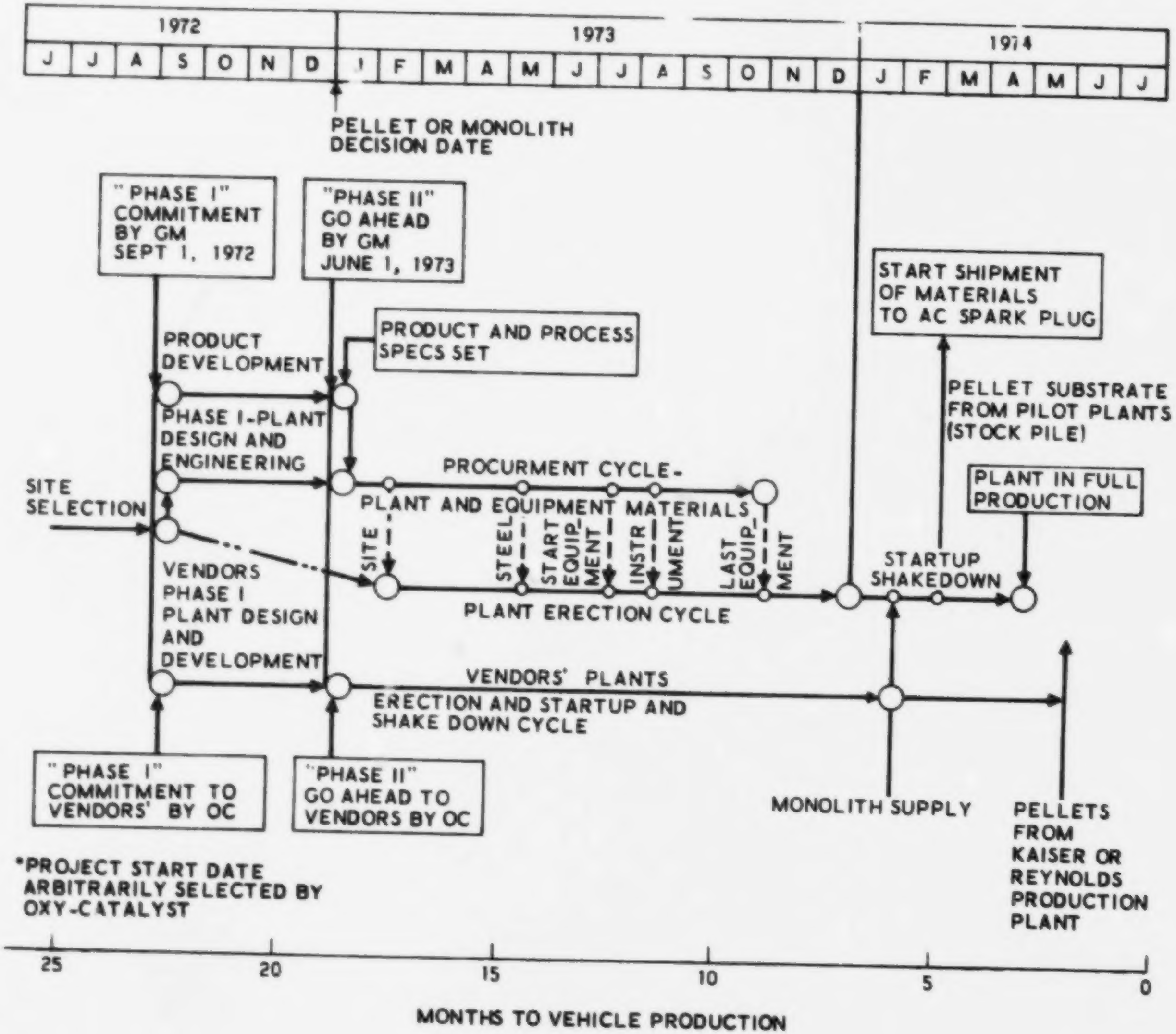
With respect to noble metal recovery from spent catalysts, Oxy-Catalyst feels that this approach might not be economically feasible, considering the handling involved in shipping the catalysts to the platinum refining plant and the cost to operate that plant. However, recovery of the platinum would certainly reduce the requirement for newly mined metal, and might indirectly result in lower platinum prices.

6.10.2 Overall Schedule

6.10.2.1 Normal Production Lead Time Schedule

Oxy-Catalyst's current estimated project schedule for pellet or monolithic catalyst plant construction is presented in Figure 6-17. This schedule was prepared by Oxy-Catalyst at the request of General Motors and is based on a start date of September 1, 1972. The important milestones of its new schedule are shown in Table 6-8. Also listed in this table are the milestones from a schedule which had been submitted by Oxy-Catalyst to EPA during the April 1972 Suspension Request Hearings.

A parallel program will be developed by Oxy-Catalyst to staff and train the personnel required to operate the plant. The training will include familiarization with its current catalyst production facilities, catalyzing procedures, pilot plant, and laboratories.


1972
1973
1974
J
J
A
S
O
N
D
J
F
M
A
M
J
J
A
S
O
N
D
J
F
M
A
M
J
J
PELLET OR MONOLITH DECISION DATE
"PHASE I" COMMITMENT BY GM SEPT 1, 1972
"PHASE II" GO AHEAD BY GM JUNE 1, 1973
PRODUCT AND PROCESS SPECS SET
PRODUCT DEVELOPMENT
PHASE I-PLANT DESIGN AND ENGINEERING
SITE SELECTION
PROCURMENT CYCLE-
PLANT AND EQUIPMENT MATERIALS
SITE
STEEL
START EQUIPMENT
INSTRUMENT
LAST EQUIPMENT
PLANT ERECTION CYCLE
VENDORS PHASE I PLANT DESIGN AND DEVELOPMENT
VENDORS' PLANTS
ERECTION AND STARTUP AND SHAKE DOWN CYCLE
START SHIPMENT OF MATERIALS TO AC SPARK PLUG
PELLET SUBSTRATE FROM PILOT PLANTS (STOCK PILE)
PLANT IN FULL PRODUCTION
STARTUP SHAKEDOWN
"PHASE I" COMMITMENT TO VENDORS' BY OC
"PHASE II" GO AHEAD TO VENDORS BY OC
MONOLITH SUPPLY
PELLETS FROM KAISER OR REYNOLDS PRODUCTION PLANT
25
20
15
10
5
0
MONTHS TO VEHICLE PRODUCTION

*PROJECT START DATE ARBITRARILY SELECTED BY OXY-CATALYST

Figure 6-17. Oxy-Catalyst Production Lead Time Schedule* (Pellet or Monolithic Catalysts)

Table 6-8. Oxy-Catalyst Plant Construction Milestones

Milestone	Lead Time, Months	
	New Schedule	Previous Schedule
Plant design and engineering	20	24
Plant procurement and erection	16	-
Plant shakedown	4	5
Plant in full production	time 0	time 0

As of September 1972, Oxy-Catalyst has made no decisions with respect to plant site location. It feels that it might be desirable to build its catalyst facility in the vicinity of a manufacturer's catalytic converter assembly plant. Although the Oxy-Catalyst schedule (Figure 6-17) is applicable to both pellet and monolithic catalysts, a decision regarding catalyst type must be made by January 1, 1973, which represents the start date for the procurement of the plant and process equipment.

The pellet catalyst plant currently projected by Oxy-Catalyst will be designed for a maximum annual capacity of 15 to 20 million pounds which is sufficient for approximately 3 million catalytic converters. The maximum capacity of the projected monolithic catalyst plant is 4 million units per year. Normally, the plants would be operated at approximately 65% of maximum capacity. Oxy-Catalyst has not provided cost data for these plants.

The production of pellet catalysts is considered a routine operation by Oxy-Catalyst. Conversely, the manufacture of monolithic catalysts may be more difficult because of potential problems related to quality control and substrate breakage and chipping. To minimize catalyst damage, Oxy-Catalyst proposes shipment of the coated monoliths in the substrate crates or in specially designed cans.

Oxy-Catalyst feels that improvements in catalyst and wash coat formulations can be incorporated as late as 4 months before the start of catalyst production.

6.10.2.2 Major Impact Factors

As indicated in Figure 6-17, procurement of the pellet substrate material represents the most critical lead time item. According to Oxy-Catalyst, Kaiser and Reynolds will achieve full production of their projected pellet substrate plants by the end of May 1974 and the beginning of June 1974, respectively, whereas Oxy-Catalyst needs the substrate material by May 1, 1974. Other critical items include the construction of the catalyst plant and the procurement of part of the process equipment. Although currently not identified as a potential lead time problem area, the design and fabrication of the required plant pollution abatement equipment might well be the most difficult technical problem.

Oxy-Catalyst estimates that a three-month compression of its currently projected lead time schedule might be possible at an increase in cost of approximately 10%. This cost increase reflects the premium payments required for equipment purchase and plant construction work.

6.10.2.3 Reduction Catalysts

The oxidation catalyst plants considered by Oxy-Catalyst are also suitable for the manufacture of pellet or monolithic type reduction (NO_x) catalysts. However, installation of an additional production line might be required for reduction catalyst manufacture. Since similar process equipment would be utilized on both lines, Oxy-Catalyst does not anticipate major difficulties in the construction and operation of a pellet or monolithic reduction catalyst facility. Conversely, different process equipment would be required to manufacture all-metal (rolled screen) type catalysts. Although procurement of this equipment might affect the required plant lead time, no serious problems related to plant construction and process design are currently foreseen by Oxy-Catalyst.

6.10.3 Major Schedule Elements

6.10.3.1 Plant Design and Construction

Upon receipt of a commitment from an automobile manufacturer, Oxy-Catalyst will proceed with the design and construction of a new catalyst plant and will initiate a program to train the personnel required to operate this plant. Oxy-Catalyst will then award a turnkey contract to an engineering firm for the design and construction of the plant and will assist in the process design and plant shakedown phases. This approach was selected by Oxy-Catalyst in order to minimize the overall cost and lead time requirement of the plant. A contracting firm has been chosen by Oxy-Catalyst. This contractor is currently evaluating some of the potential problem areas associated with the design and construction of a catalyst plant. The interrelationship between Oxy-Catalyst, contractor, and substrate and material suppliers is illustrated in Figure 6-18.

6.10.3.2 Equipment and Material Procurement

Oxy-Catalyst has identified the following process equipment for its projected pellet and monolithic catalyst plants.

Pellet Catalysts

- Storage bins
- Mixing and holding tanks
- Mixers
- Pumps and blowers
- Blenders
- Feeders
- Dryers
- Calciners
- Product coolers
- Classifiers (screens)
- Dust collectors
- Pollution abatement equipment
- Material handling equipment
- Quality control instrumentation

Monolithic Catalysts

- Warehouse facilities
- Mixing and holding tanks
- Mixers
- Pumps and blowers
- Spraying equipment
- Dryers
- Calciners
- Product coolers
- Dust collectors
- Pollution abatement equipment
- Material handling and packaging equipment
- Quality control instrumentation

All of these components are conventional in nature except perhaps for the pollution abatement equipment required for treatment of the

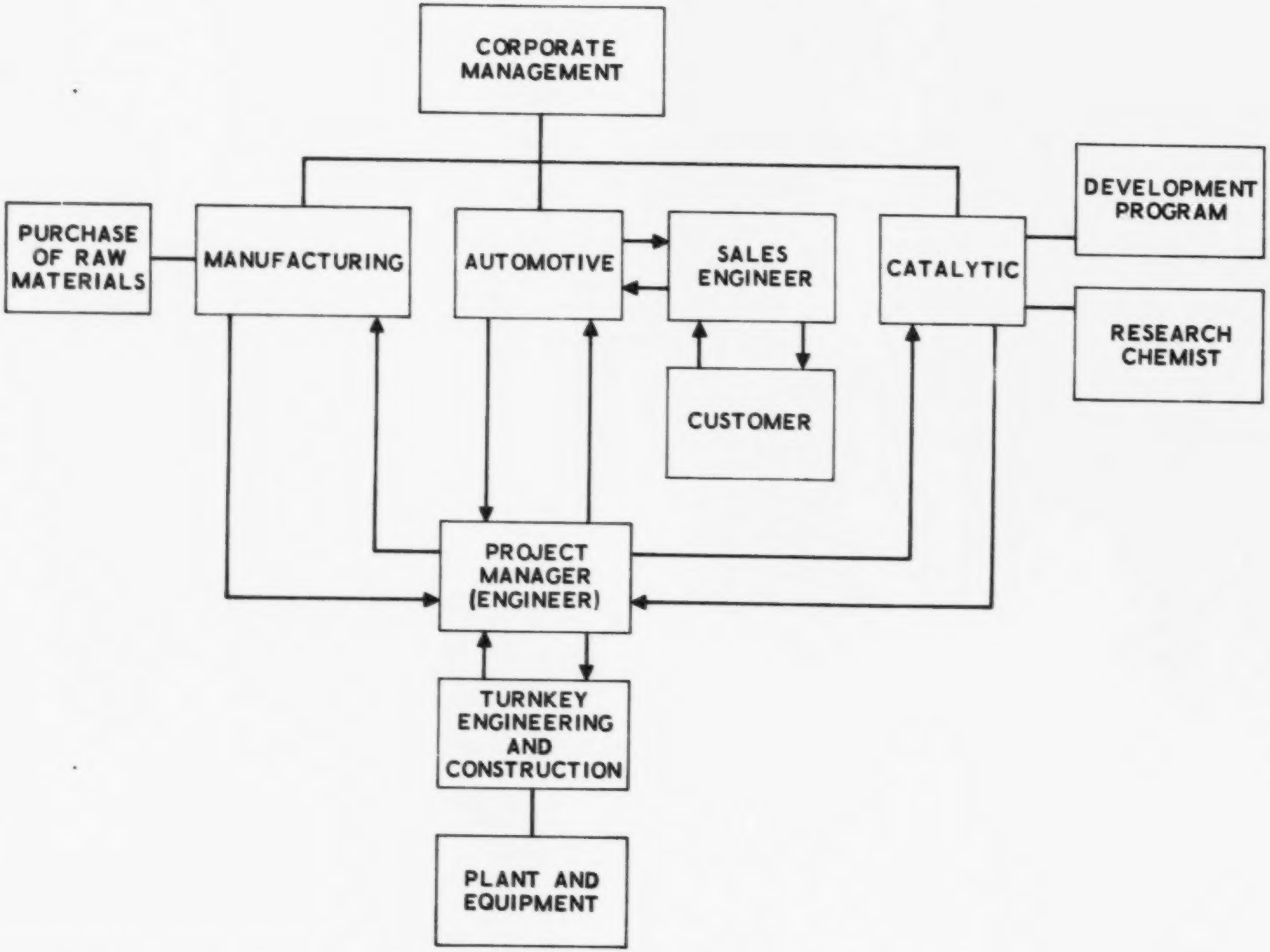

CORPORATE MANAGEMENT
PURCHASE OF RAW MATERIALS
MANUFACTURING
AUTOMOTIVE
SALES ENGINEER
CATALYTIC
DEVELOPMENT PROGRAM
RESEARCH CHEMIST
CUSTOMER
PROJECT MANAGER (ENGINEER)
TURNKEY ENGINEERING AND CONSTRUCTION
PLANT AND EQUIPMENT

Figure 6-18. Oxy-Catalyst/Contractor/Supplier Relationships; Oxidation Catalyst Plant

off-gases and solid waste produced in the catalyst manufacturing process. Oxy-Catalyst does not anticipate a lead time problem related to the procurement of this equipment. All plant equipment will be procured from outside sources, except for the pollution abatement equipment which will be designed and built by Oxy-Catalyst.

Oxy-Catalyst has no intention of manufacturing substrates and wash coat compounds. Kaiser and Reynolds are considered potential pellet substrate suppliers. Tests conducted by Oxy-Catalyst revealed little difference in the physical properties of the Kaiser and Reynolds pellets, although different manufacturing processes are used by these two companies. No problems are foreseen by Oxy-Catalyst for either pellet type with respect to porosity, crushing strength, and shrinkage at high temperatures.

The monolithic substrates might be procured from American Lava and/or Corning. Aluminum Company of America (Alcoa), Kaiser and Reynolds are potential alumina suppliers. Based on current estimates, an adequate supply of monoliths will be available from American Lava and/or Corning by March 1, 1974 to satisfy the catalyst needs of General Motors. However, in the case of pellet catalysts, stockpiling of substrate material from the Kaiser and Reynolds pilot operations would be required, since initial substrate delivery from their new plants is scheduled for the end of May 1974 (Kaiser) and the beginning of June 1974 (Reynolds). Most likely, Oxy-Catalyst will not get involved in the procurement of noble metals and catalyst canisters. This will be handled directly by the automobile manufacturers.

6.10.3.3 Plant Startup

As indicated in Figure 6-17, Oxy-Catalyst allocates a four-month period for plant startup and shakedown. This period, which was selected by Oxy-Catalyst on the basis of its experience in catalyst manufacture, provides a reasonable margin of safety in the event of unexpected difficulties. Oxy-Catalyst feels that some catalysts would be produced during that period which would then be available to the automobile manufacturers for test purposes and/or stockpiling.

6.10.4 Quality Control and Warranty

Since the catalyst specifications have not been released by the automobile manufacturers, Oxy-Catalyst has not been able to establish firm quality control requirements and test procedures. However, Oxy-Catalyst has concluded that certain tests will be required to monitor a number of substrate, washcoat and active metal layer properties, including product density, porosity, metal loading, and loading uniformity.

Oxy-Catalyst states that the question of catalyst warranty must be resolved jointly by the catalyst and automobile manufacturers. Although it will guarantee its product in terms of meeting the specifications, Oxy-Catalyst will not be able to guarantee the performance of the catalyst in the car because catalyst operation and performance are also affected by the operating conditions of the other emission control system components installed in the vehicle.

6.10.5 Pilot Plant

Oxy-Catalyst has essentially completed the construction of a pilot plant for pellet catalysts. This plant is designed to produce pellet catalysts in a continuous process at the rate of approximately 250 pounds per hour. Previously, all Oxy-Catalyst pellet catalysts had been manufactured by a batch procedure. The pilot plant (excluding air pollution abatement equipment) is approximately 15 feet high and uses a floor area of approximately 150 square feet. This plant will be used by Oxy-Catalyst primarily to optimize catalyst manufacturing procedures. The full-size pellet catalyst plant will be an enlarged version of the pilot plant. Oxy-Catalyst has no current plans to build a pilot plant for monolithic catalysts.

6.10.6 Current and Pending Contractual Agreements

Although Oxy-Catalyst has conducted a considerable amount of catalyst development work in conjunction with General Motors, it currently has no commitment for catalysts from an automobile manufacturer. However negotiations with General Motors are proceeding.

6.11 REYNOLDS METALS COMPANY

6.11.1 Company Experience and Products

6.11.1.1 Automotive and Nonautomotive Products

The Reynolds Metals Company is a major producer of forged, cast, and sheet mill aluminum products for a wide range of commercial industries (automotive, aircraft, building, electrical, highway, machinery, consumer goods). In the automotive area, a Reynolds-developed aluminum alloy is used in the Chevrolet Vega engine. The company is also working with auto producers to design lightweight aluminum bumpers and backup beams to meet new federal safety standards.

6.11.1.2 Automotive Catalyst-Related Products

Reynolds' principal automotive product bearing on the issue of 1975/76 vehicle production lead time requirements is an alumina support for pellet-type oxidation catalysts. Reynolds could produce the pellets in bulk quantity for supply to either a catalyst manufacturer or automobile manufacturer for deposition of the active catalytic material on the pellet substrate.

As extruded and cut (0.1 inch diameter; about 0.25 inch long), the alumina supports (beads, pellets) are plastic and do not stick together. Some heat treatment is required before the extrusion process to remove excess moisture. Several alumina phases can be obtained in the dehydration process, depending upon the selected temperature versus time profiles. At 1800 degrees Fahrenheit, the low surface area forms of alumina (alpha phase) begin to occur. At 2200 to 2500 degrees Fahrenheit, there are large occurrences of alpha alumina.

The high surface area desired in the alumina support is developed in the heat treatment process (which is proprietary) and is the key to the required porosity. In November 1971, Reynolds adopted a single treatment process to give the auto companies a stable product with consistent qualities and to afford a valid basis for evaluation. This treatment has been maintained since that date. However, Reynolds' proposed production plant heat treatment facilities would be flexible enough to incorporate any heat treatment improvements that might evolve in the course of further research. Reynolds' proposed specifications for experimental alumina supports are presented in Table 6-9.

Table 6-9. Reynolds Proposed Specifications for Experimental Alumina Supports, 6 x 8 Mesh; Nominal 0.100 in. Diameter (August 11, 1972)

SHAPE: Rounded Cylinders (Not Spheres)

MEAN DIAMETER: 0.100 in. ± 0.005 in.

MEAN L/D: 1.3/1 to 1.7/1 (Based on piece count, not weight)

U. S. STD. SCREEN ANALYSIS

+5 Mesh (0.157 in. opening)
+6 Mesh (0.132 in. opening)
+7 Mesh (0.111 in. opening)
+8 Mesh (0.0937 in. opening)
-8 Mesh

CHEMICAL ANALYSES

Loss on Ignition @ 1000°C (%)	<5.0
*Min Al_2O_3 (%)	99.6
*Max Na_2O (%)	0.10
*Max SiO_2 (%)	0.10
*Max Fe_2O_3 (%)	0.05
*Max CaO (%)	0.06

(* on 0% LOI or calcined basis)

SURFACE AREA (BET METHOD):
180 M^2/g minimum
200 M^2/g typical

BULK DENSITY: 32 - 36 lb/ft^3
34.0 lb/ft^3 typical

APPARENT DENSITY: 0.85 - 0.94 g/cc
(Of an individual cylinder) 0.88 g/cc typical

ABSOLUTE DENSITY: 3.15 - 3.35 g/cc
(Of an individual cylinder) 3.25 g/cc typical

TOTAL PORE VOLUME: 0.750 - 0.880 ml/g
(Of an individual cylinder) 0.830 ml/g typical

Volume of Pores >500Å Diameter: >0.320 ml/g typical

CRUSH STRENGTH (total load): 5.0 - 10.0 lb
7.0 lb typical

AIR ATTRITION LOSS: <10%
6% typical

Typical Pore Analysis via Hg Porosimeter

Diameter (Microns)	Volume (ml/g)
+10	0.027
+5	0.046
+3	0.073
+2	0.106
+1.5	0.132
+1	0.165
+0.5	0.206
+0.3	0.238
+0.1	0.301
+0.07	0.324
+0.05	0.338
+0.035	0.360

Current Reynolds alumina supports have much less than 5% volume shrinkage when exposed to 1832 degrees Fahrenheit for 24 hours.

Reynolds is also a major supplier of raw material for the alumina portion of the monolith support produced by American Lava. (Typically, monoliths contain about 30% alumina.) Alcoa is the major supplier of similar materials to Corning for the production of the Corning monolithic substrate.

6.11.1.3 Automotive Catalyst/Substrate Test Programs

Reynolds in-house test programs are limited to determinations of the physical properties of its pellet substrate product. These include pellet size screening, chemical content analyses, surface area, bulk density, apparent pellet density, absolute pellet density, total pellet pore volume, crushing strength, and attrition characteristics.

Reynolds has no specific cooperative programs with automobile manufacturers. Reynolds merely supplies the pellet substrates to catalyst manufacturers, as requested.

6.11.1.4 Current Research Programs

Research is continuing to improve pellet characteristics, particularly with regard to crushing strength and attrition loss improvements. In general, this is related to heat treatment processing changes.

6.11.2 Overall Schedule

6.11.2.1 Normal Production Lead Time Schedule

Reynolds has estimated that 18 months are required to produce its alumina supports in production quantities. This 18-month period would commence with the receipt of a firm purchase order and include the following:

a. Preliminary engineering (3 months)
b. Plant and equipment construction (12 months)
c. Plant startup (3 months).

The plant being considered would be a new one, approximately 20,000 square feet in size, adjacent to its existing Arkansas facilities, and would be used only for its alumina support product and nothing else. For this reason, Reynolds has concluded that it must have a firm three-year commitment before proceeding with plant construction.

Based on such a plant operating at full capacity (approximately 12,000,000 pounds per year), it estimates a product price of $0.41 per pound f.o.b. Bauxite, Arkansas (freight rates to East or Midwest should be less than one cent per pound). However, the product price would have to be reconsidered if the specifications were changed significantly.

Reynolds estimates a capital investment cost of $4 to $5 million for the production plant facility.

6.11.2.2 Major Impact Factors

As noted above, the limiting schedule factor is construction of the plant and equipment. All items of process equipment (mixers, extruders, kilns, etc.) are conventional in nature and represent nothing unusual in the way of procurement or manufacture. Reynolds does feel that the heavy electric drive motors required (for mixers, rotary kilns) would most likely represent the most critical item with respect to lead time, since they are not normally off-the-shelf items and require manufacture to customer specifications.

The raw materials for the alumina supports are produced in copious quantities. Reynolds states it could operate its Arkansas plant for 20 years, supplying the whole automotive industry with alumina supports, without making a dent in its proven reserves at that location. Current alumina production at the Bauxite, Arkansas plant is several hundred thousand tons per year.

At the present level of schedule definition, Reynolds does not feel that any significant amount of compression is achievable. Although some processing equipment might be obtained with approximately 10% time compression (at considerable cost increase), it doubts that the acquisition of heavy drive motors could be accelerated.

6.11.2.3 Reduction Catalysts

The Reynolds pellet substrate could be used for reduction catalysts as well as oxidation catalysts.

6.11.3 Major Schedule Elements

6.11.3.1 Plant Design and Construction

Reynolds would do its plant engineering in-house. Chemical flow process diagrams for the production facility have been completed, but Reynolds still has the plant design effort to go through. Reynolds' current price quotations and production schedules have been based on historical values for dryers, buildings, etc.

Reynolds is as yet undecided on whether to construct its own plant or have an independent contractor do the work.

6.11.3.2 Equipment and Material Procurement

The alumina raw material is the result of calcining hydrated alumina. Processing the alumina into the finished pellet support requires the following:

a. Mixers (to produce a plastic state suitable for extruding)
b. Extruders (to extrude the plastic alumina)
c. Cutters (to cut the extruded product to the proper length)
d. Dryers and heat treaters (to produce the desired porosity and chemical state)
e. Drive motors (to power the various equipment)

As Reynolds product is based on its own raw materials (Table 6-9) and necessarily involves its own proprietary heat treatment processes, there is no issue involving internal vs external procurement of the product or portions thereof. Processing equipment (mixers, rotary kilns, extruders, etc.), of course, would be procured from outside suppliers.

6.11.3.3 Plant Startup

Reynolds considers the production of its alumina supports as a routine manufacturing operation. It envisions no difficulty in starting up and checking out the plant and equipment during the three-month period allocated for this purpose.

6.11.4 Quality Control and Warranty

Quality control specifications have not been considered at a detailed level. Normal product warranty provisions (i.e., that the product meets procurement specifications) are envisioned.

6.11.5 Pilot Plant

A small pilot plant assembly line was completed in July 1972 in Reynolds research plant in Arkansas. This pilot plant can produce thousands (up to 5000) of pounds per month of alumina supports. Several thousand pounds have been shipped to a number of catalyst and automotive manufacturers for testing.

6.11.6 Current and Pending Contractual Agreements

Reynolds has no firm contractual agreements with either catalyst or automotive manufacturers. Reynolds has provided quotes on its pellet substrates to Davis Chemical, Oxy-Catalyst, and Monsanto, who were, in turn, quoting on potential General Motors catalyst requirements in the August through September 1972 time period.

6.12 UNIVERSAL OIL PRODUCTS COMPANY

6.12.1 Company Experience and Products

6.12.1.1 Automotive and Nonautomotive Products

Universal Oil Products Company (UOP) is a worldwide organization engaged in the research, development, operation and/or licensing of processes for use by the petroleum refining industry. Several divisions within UOP are active in the design, development, marketing and servicing of hardware and facilities for air, solid waste and water pollution abatement. UOP also produces truck and passenger car seats. Both are sold to the domestic automobile industry, while the specialized truck and other vehicle seats are marketed throughout the world.

UOP has been active in the research and development of noble and non-noble metal catalyst formulations, spherical pellet substrates and the application of the wash coat and catalyst to monolithic substrates, as well as the design, prototype manufacture and installation of catalytic converter systems.

6.12.1.2 Automotive Catalyst-Related Products

UOP is hoping to supply a finished catalyst, without canisters, to the auto industry. Although its Flexonics Division is capable of producing canisters and has done so for UOP prototype catalytic converters produced for durability tests, UOP does not expect to compete in this area.

There are several ways in which UOP could act as a supplier to the automotive industry:

a. UOP could produce its own pellet substrate and also apply the catalytic material to the substrate.

b. Alternately, UOP could buy the pellet substrate from another company, e.g. Kaiser, and then add the catalyst. UOP indicates that this might result in a lower cost but could also result in a pellet with lower surface area. The UOP pellets have an average bulk density of 0.33 gram per cubic centimeter, whereas, the density of the Kaiser pellet was reported by UOP to be 0.56 gram per cubic centimeter.

c. If a monolithic substrate was required, UOP would buy the unit from American Lava or Corning and apply the alumina wash coat and catalyst material, since UOP does not have the capability of producing the monolithic substrate. UOP also indicates that, for General Motors units, the substrate might be supplied by the AC Spark Plug Division of General Motors Corporation.

In spite of the current trend toward the noble metal, monolithic catalytic converter, UOP expresses the opinion that base metal catalysts will eventually dominate the market, primarily because of cost considerations. It also feels that pellet designs have, generally, yielded lower back pressures and provide the potential advantage of being easier to recharge or refurbish. (This is in direct contrast to a statement made by American Lava that General Motors had indicated that the pellet catalysts produce higher back pressures than monoliths and that pellets could not be used for both oxidizing and reducing catalysts.)

6.12.1.3 Automotive Catalyst Test Programs

UOP has provided catalytic converters to both domestic and foreign automobile manufacturers for test and evaluation. UOP reports that most auto manufacturers, including Ford, Chrysler, General Motors, Toyota and Volkswagen, currently favor the noble metal, monolithic catalyst. It is, however, still getting orders for test samples of pellet catalysts from various companies and that pellet testing is still active. UOP reports that General Motors had recently accumulated 52,000 miles on the UOP PZ-214 base metal pellet catalyst. Emission levels were, according to UOP, within the 1975 standards, although no specific details were given. The test is reported to be continuing.

6.12.1.4 Current Research Efforts

Current research efforts by UOP deal with the development of catalyst designs utilizing less platinum. UOP's latest precious metal blend is predominantly palladium. This combination has been found by UOP to provide a better conversion efficiency than straight platinum at a proportionate reduction in cost. Palladium has been variously quoted at

$35 to $60 per ounce, while platinum is approximately $140 per ounce. UOP is currently generating data to establish the optimum palladium/platinum ratio for minimum emissions.

UOP pellet substrates are currently 0.125 inch in diameter. General Motors has asked if UOP could produce 0.25 inch diameter pellets to reduce exhaust back pressure. This is also undergoing development by UOP.

6.12.2 Overall Schedule

6.12.2.1 Normal Production Lead Time Schedule

UOP indicated that regardless of which catalyst they contract to supply to industry, new facilities would have to be built. The projected schedule, shown in Figure 6-19, was prepared by UOP prior to any contractual commitments, but was verified as still being valid subsequent to a recent agreement between UOP and Chrysler (see Section 6.12.6).

The plant location was not revealed by UOP but it did indicate that several site locations were being considered, including Fayetteville, Arkansas, Owensburg, Kentucky, and Tulsa, Oklahoma. Primary considerations in site selection are said to include the need for large quantities of water and fuel, preferably natural gas, in addition to an adequate labor supply.

The UOP production capacity for monolithic catalysts is planned at 8 million units per year based upon a three-shift per day, five-day per week operation. This includes the number of units scheduled for production for Chrysler, but since the details of that agreement have not been released, UOP declines to discuss the production level scheduled for Chrysler.

Plant facilities required to meet the planned production capacity would require a total of approximately 93,000 square feet, excluding kilns, which would be located between the process buildings to reduce the heat load in the buildings. The plant floor area is itemized in Table 6-10.

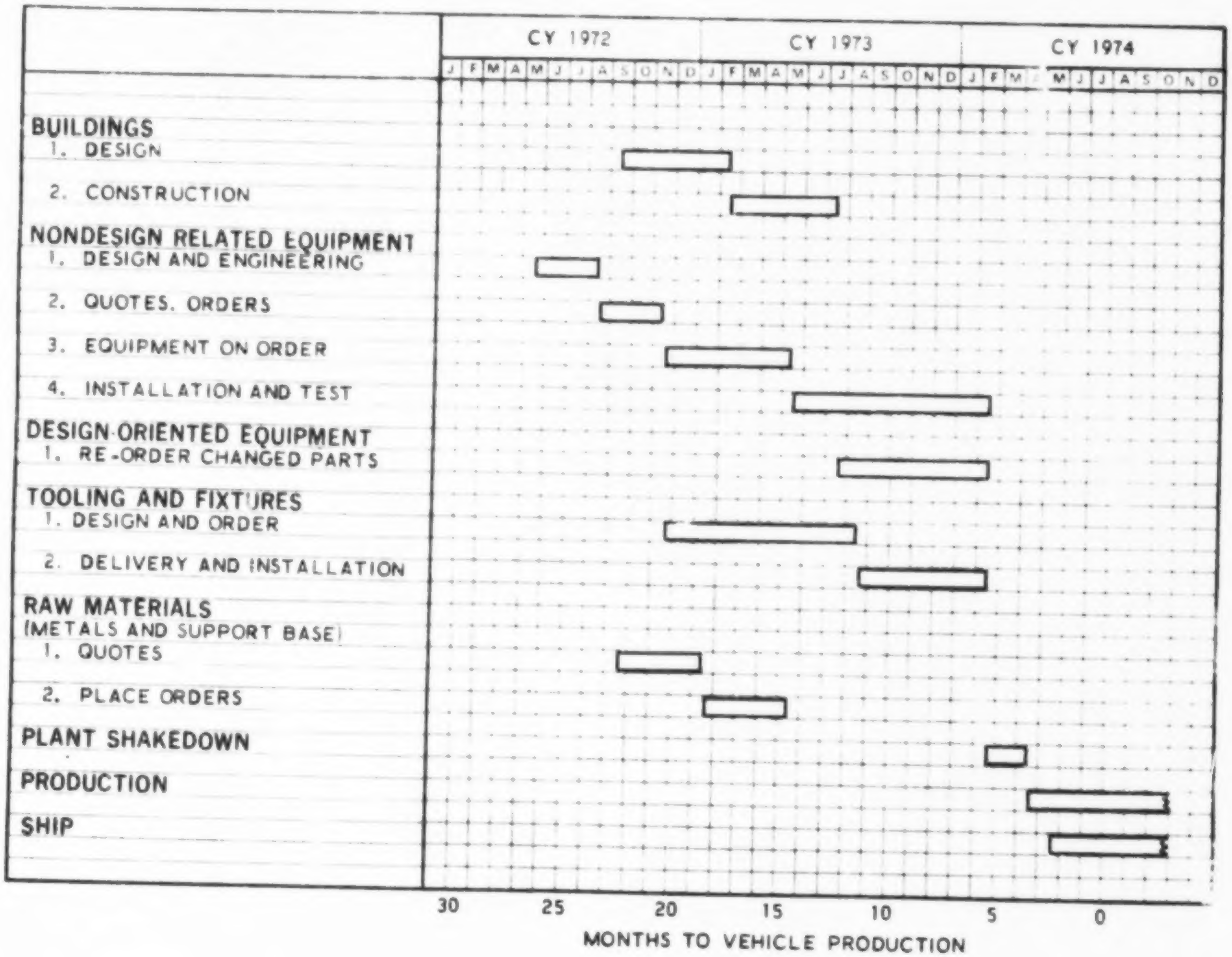


Figure 6-19. UOP Production Lead Time Schedule

Table 6-10. UOP Catalyst Plant Floor Area Requirements

Facility	Floor Area, ft^2
Process Bldg No. 1	50,000
Process Bldg No. 2	12,000
Maintenance	8,000
Offices	7,000
Laboratories	8,000
Employees Welfare (Showers, Lockers, etc.)	8,000
Total	93,000

In addition to the development of the pellet substrates for catalytic converters, UOP also has done extensive research and development work associated with the monolithic substrate. The major areas of effort have been concerned with the development of a high surface area coating (wash coat) bonded to the substrate, with particular emphasis on the resistance to spalling when subjected to prolonged temperature cycling. In addition, it has been active in the development of a stabilizer which inhibits phase transitions and area loss of wash coat.

Experience gained in the development of coating and catalyzing techniques for monolithic substrates has contributed to the design of production facilities planned by UOP.

6.12.2.2 Major Impact Factors

UOP has stated that there is no one identifiable critical item in its production lead time schedule (Figure 6-19). UOP has, in essence, stated that if a commitment was made by September 15, 1972, it could meet the production delivery date indicated in the schedule. A partial commitment has been made by Chrysler and UOP is in the process of implementing its schedule.

UOP indicates that it might be possible to accomplish some reduction in the schedule, primarily during the facilities construction phase.

UOP feels that one month to six weeks could be cut from this period through the use of overtime labor. Cost penalties are not identified by UOP.

6.12.2.3 Reduction Catalysts

UOP is working on the development of a dual coating technique, for pellets and for monoliths, which produces a catalyst suitable for either reduction or oxidation. It is also working on the development of a reduction catalyst that can be applied either to a pellet or monolithic substrate.

Catalyst production would require the building of additional new facilities. Approximately the same lead time requirement as shown for 1975 production would be necessary, if a separate reducing catalyst was required. If the dual coating were to be used in a pellet configuration, the schedule could be significantly compressed because the coating processes and equipment have already been developed.

6.12.3 Major Schedule Elements

6.12.3.1 Plant Design and Construction

UOP has indicated that work will start on the foundations for the monolithic catalyst plant facilities on December 1, 1972. This is approximately 2-1/2 months ahead of the schedule originally prepared by UOP.

UOP is also proceeding on the design engineering and contract preparation for a pellet manufacturing facility since General Motors has indicated that it will make a final decision by December 31, 1972 on whether to order pellet or monolithic converters.

6.12.3.2 Equipment and Material Procurement

UOP does not foresee any problem in obtaining adequate supplies of alumina for use in the manufacture of pellets or for the wash coat.

Under the terms of the agreement with Chrysler, UOP has stated only that Chrysler will contract separately for the monolithic substrates, for delivery to UOP. To date, a substrate supplier had not been selected by Chrysler. No other details are currently available.

In this connection, Corning has indicated to UOP that monolithic substrate specifications and production quantities would have to be defined by September 1, 1972, or Corning would not have sufficient time to develop the necessary facilities for production.

UOP's basic production tooling and equipment is reported to be very conventional chemical process apparatus. These were identified only in general terms, such as blenders, mixers, digesters, impregnators, pressurizers, conveyors, aging tanks, heat exchangers, drop towers and furnaces. If UOP were to manufacture pellet substrates, the longest lead time items are reported to be certain process equipment with nickel-steel or glass-lined steel equipment which would take about ten months for delivery.

The design of equipment to be used in the application of the wash coat to the substrate has been completed and one unit is on order and is scheduled for delivery on March 1, 1973. Additional units will be ordered at a later date.

Nondesign and design related equipment was defined by UOP in a similar manner to that given by Corning: the nondesign related equipment is not dependent on knowing the finished dimensions of the monolith while the design related equipment is dependent on the finished dimensions. UOP has indicated that the latest possible date for re-ordering design related equipment due to a change in the monolith dimensions is mid-July 1973, with an attendant delivery period of seven months (Figure 6-19).

6. 12. 3. 3 Plant Startup

As indicated in Figure 6-19, UOP has allowed two months for plant shakedown, with delivery to start in mid-May 1974, one month after the start of production.

6. 12. 4 Quality Control and Warranty

Quality control procedures and equipment are not specifically delineated by UOP. UOP does indicate that it is currently producing pellets to specifications covering size, crushing strength, porosity, and abrasive resistance. General Motors has asked if UOP would be willing to accept a performance specification on durability and performance for the finished catalytic converter. UOP has tentatively agreed, but a final decision is dependent upon a precise definition of the requirement.

6.12.5 Pilot Plant

UOP operates pilot plant facilities as a part of its research laboratory. Production capacities are not disclosed, but it is stated that many of the processes are essentially a hand operation.

UOP does indicate, however, that General Motors requirement for a preproduction shipment of approximately 30,000 catalysts in April or May of 1974, could be handled by UOP's existing manufacturing equipment.

6.12.6 Current and Pending Contract Agreements

An agreement was recently signed by UOP with Chrysler involving the design, engineering and site preparation for a manufacturing facility "with a capability of providing a substantial part of Chrysler's 1975 catalyst requirements." A separate contract would be negotiated for actual plant construction and for a specific production output.

Current indications from UOP are that Chrysler would contract for the monolithic substrate from an as yet unidentified vendor and UOP would apply the wash coat and catalyst. It is not known whether Chrysler or UOP would contract for the required palladium and platinum although Chrysler has announced that it has negotiated a contract with the Soviet Union for the delivery of 100,000 troy ounces of palladium in 1973.

UOP states that it has also been talking and negotiating with Ford, General Motors, Volkswagen and Toyota. UOP also indicates that it has not been in contact with American Motors for some time.

General Motors has directed UOP not to bid on the platinum required for any General Motors units, since the number of recent bidders has driven the price up. General Motors indicates it would carry out the procurement process for UOP or others.

In dealing with UOP and other catalyst suppliers, the automobile companies have been insisting on a technology sharing contractual arrangement which would require vendors to release their processes, royalty free, to other auto company sources of supply. UOP has agreed (reluctantly) to accept these terms. However, UOP feels that future advances in process development will soon make these shared processes obsolete so that the individual vendors could again acquire exclusive manufacturing techniques. A similar situation was also reported by American Lava (See Section 6.2).

SECTION 7

LEAD TIME SCHEDULES FOR AUTOMOBILE COMPONENT MANUFACTURERS

This section presents normal production schedules, major impact factors, and critical lead time items and discusses major elements in the schedules for automobile component manufacturers. Production lead time data were obtained from various manufacturers based on both recent and current experience. However, for ease of comparison, the data are presented in the 1975 model year time frame. Figure 7-1 presents a summary of the overall production lead times for various components from receipt of order to the automobile manufacturer's Vehicle Job No. 1. This type of presentation is used throughout this section. Noted on Figure 7-1 are some of the more common major impact factors associated with component lead times. For example, the typical transmission lead time is about seven months for reorder of a type that is in production. If a new transmission is ordered the lead time increases to 19-1/2 months.

For this discussion, tooling is defined as those items which are attached to production equipment in order to perform an operation. The set of production equipment to perform all operations on a component is defined as a production line. For example, to form a body part, the tooling is the dies that perform the operations such as bending, shearing, and piercing. A press containing one die set is a piece of equipment. The production line is comprised of all the presses, their dies, equipment to transfer panels between presses, and so forth, which are necessary to completely make a set of body parts.

One of the key dates for a component supplier is the date required for delivery of production samples to the customer. These samples are made from the equipment and tooling that will be used during the actual production run, and the parts are representative of the production parts.

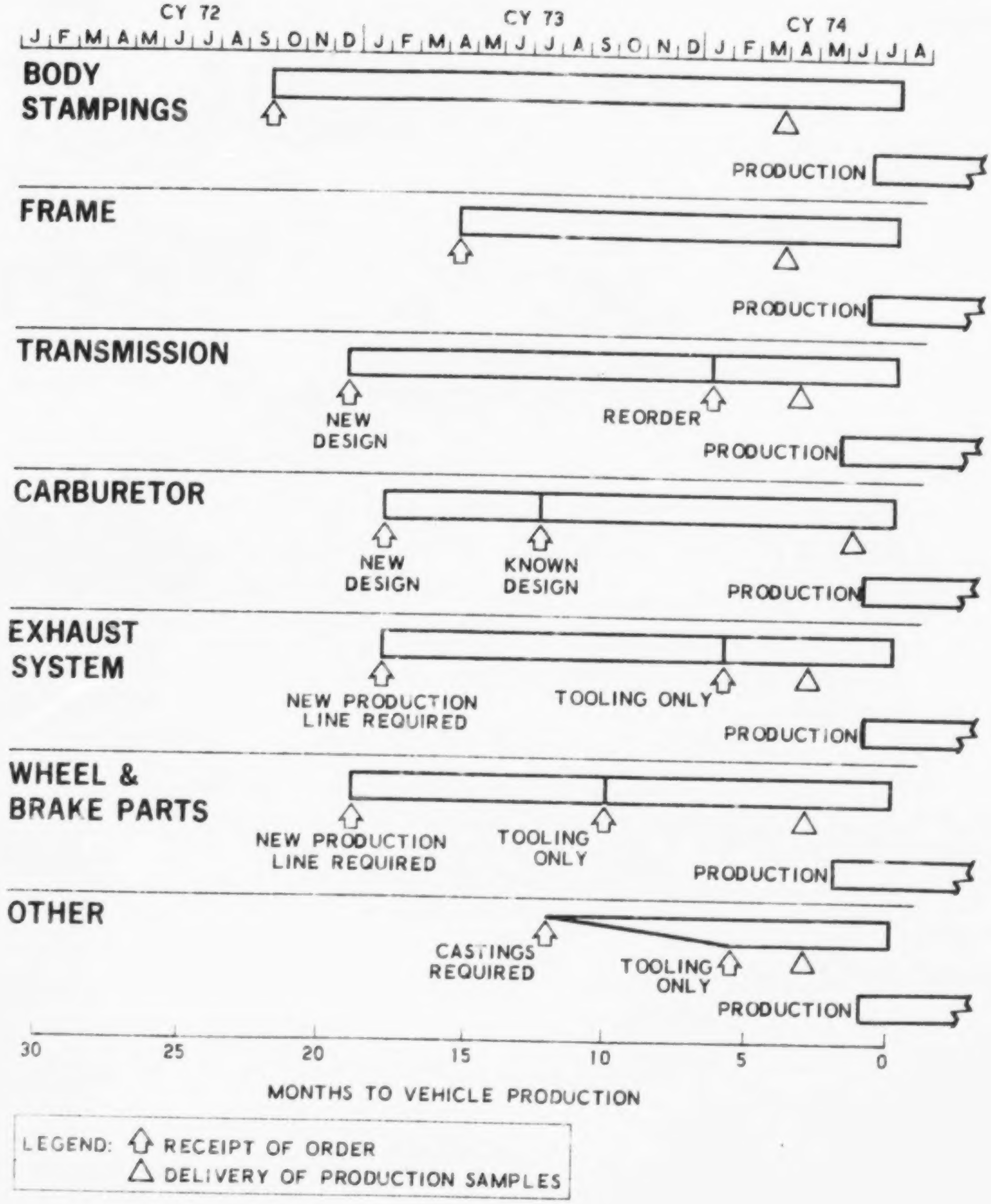


Figure 7-1. Automobile Component Manufacturers' Overall Production Lead Time

The production samples are delivered to the customer for approval, and the customer in turn uses the production samples for testing or to build a pilot lot of car models.

Although actual production deliveries begin some months after these samples are delivered, the component manufacturer continues to develop his production line. He may need to eliminate problems from the line, or he may install additional equipment needed for volume production rates but which was not necessary for the fabrication of the samples. He may make preproduction runs to verify production rate or to build up parts inventory.

Inventory of production parts is an important aspect of cost and scheduling. The automobile manufacturers keep an absolute minimum inventory of components, subassemblies, and cars. In general, the inventory of components and subassemblies consists of those in transit from the suppliers. To keep production lines rolling, the supplier is forced to carry most of the inventory. The following sections discuss each of the component manufacturer schedules in detail.

7.1 LEAD TIME SCHEDULES FOR BODY STAMPINGS

The body of the automobile for a body and frame type manufactured car and for that of a unitized construction car is made up of a series of panels that are stamped from sheet metal. The sheet metal is supplied in coiled form and, following decoiling, a "blank" for the particular part is sheared by a hydraulic press operated die. The final shape is stamped by a series of hydraulic press operations. A single panel might require as many as 17 die sets. The panels for a complete automobile, such as the Lincoln panels made by The Budd Company, require 550 die sets for major sheet-metal stampings, without counting the floor pans.

Figure 7-2 illustrates a roof panel stamping operation at Budd for the Ford Econoline van. The completed and unpainted panels are protected from rust and then shipped to the automobile manufacturer's assembly plant. Rail shipment limits the panel size to 8 feet in width by 9 feet in height. Where shipment by truck is necessary, the maximum width allowed is 7 feet.

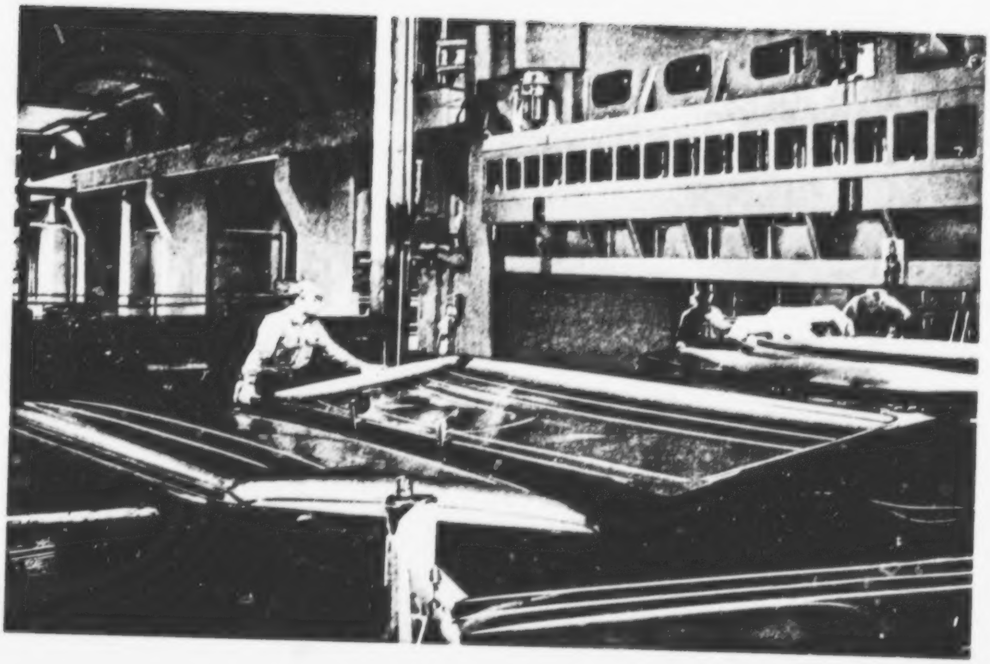


Figure 7-2. Extended Roof Panel for the Ford Econoline Van

7.1.1 Normal Production Schedule for Body Stampings

A normal production schedule for producing body stampings is shown in Figure 7-3. The schedule is based on past experience, but is indexed to the 1975 model year for ease of comparison. It is seen that the commitment for production of stampings is required 22 months prior to vehicle production. The normal schedule is predicated on availability of existing plant capacity to produce the stampings and on no requirements for new capital equipment.

For the press shop operation performed by Budd Company, model changeover does not usually require major changes to the fabrication and transfer process. In general, new dies are simply placed in the presses. As a rule of thumb, the same parts production line runs 10 to 20 days on one model and is then changed over to another model.

7.1.2 Major Impact Factors for Body Stampings

The factors that can have a major impact on the lead time for body stampings are (a) insufficient plant capacity requiring a new facility and (b) the need for new capital equipment. Although it was not specifically cited for body stampings, the lead time associated with a new facility is on the order of 36 months prior to vehicle production.

If new capital equipment is required, its associated lead time will cause an increase in the overall normal body stamping lead time to some degree depending on the amount and type of equipment. Tabulated below are representative pieces of major production line equipment with their associated lead time.

Major Equipment Used	Normal Lead Time Including Installation (in months)
Decoiling, straightening and feeding system 96 inches	15
Double Action Press, 2000 Tons	15
Single Action Press, 1000 Tons	13
Single Action Press, 800 Tons	8

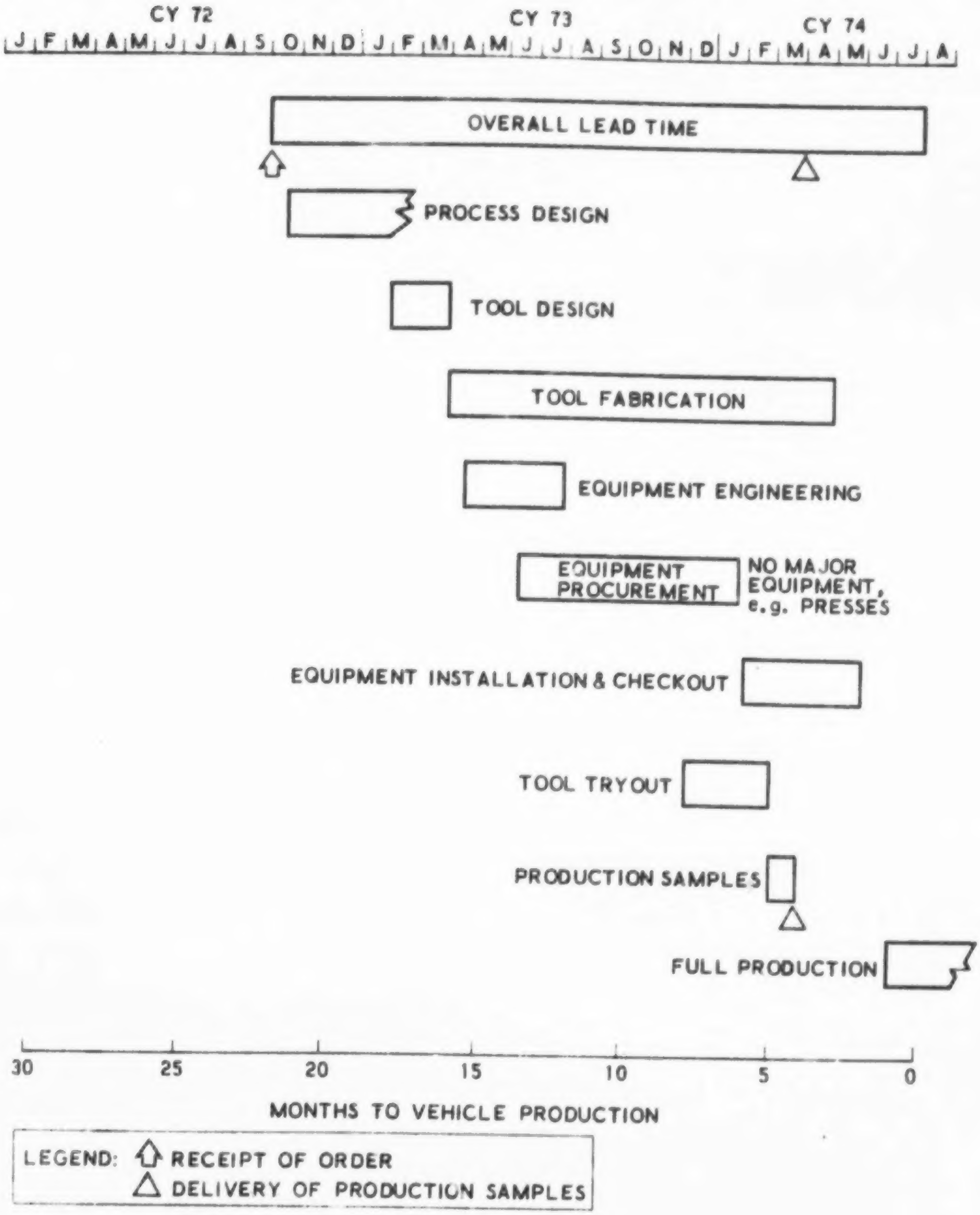


Figure 7-3. Body Stamping Lead Time

7.1.3 Critical Lead Time Items for Body Stampings

As noted from Figure 7-3, tooling is the critical lead time item. Tooling consists mainly of dies and the assumption is made that an existing production line type press shop (presses with replaceable dies) can produce the parts with only minor changes to the equipment. As an example, details for the lead time of typical dies are given as follows:

Design of the Dies	8 to 9 weeks
Polystyrene Pattern for Dies	6 to 8 weeks
Meehanite Castings for Dies	4 to 5 weeks
Machining of Dies	7 to 12 weeks
Installation of Dies	1 to 2 weeks
Time to Initial Tryout (Summation of above)	26 to 36 weeks

These figures are for single die sets; a group of die sets would require longer times. The rear quarter panel is the worst case and requires the maximum time of 36 weeks. The total time period to produce all die sets is approximately 13 months as shown in Figure 7-3.

The use of dies in presses requires blank holder development which is included in Figure 7-3 with Tool Fabrication. The blank holder is required to hold the sheet metal blank to prevent wrinkling, splitting, or overstressing. It is of interest that in almost all cases a group of die sets is built only once for a given model body panel. If the die wears or is damaged, repairs are made by welding. A single die can be used for 1 million stampings of complex shapes and for up to 15 million stampings of simple shapes. This is not true for "soft tooling" which allows only 1000 to 10,000 stampings.

7.1.4 Major Elements in Body Stamping Schedule

The major elements of the body stamping schedule begin with process design where the sequence and details of the blanking, forming, and cutouts of each panel are worked out and the major equipment to be used is established. Following this, tooling design and fabrication is performed as discussed in Section 7.1.3.

Other items of equipment are specified and negotiated with the equipment vendors. Customer approval is secured and the equipment is ordered, received, installed and checked out. Typical equipment items and their lead times are as follows:

Equipment Item	Lead Time (months)
300 KVA Transformer	4
Solid State Controls for 300 KVA	3
Press Type Feeder	5
Press Type Extractor	5

It is noted that these items of equipment are only needed on-line prior to production, rather than prior to making the set of production samples, which can be run off at a slow rate.

During the equipment acquisition period, tool tryout is conducted where sample pieces are made from the new dies and checked against the drawings. If required, the dies are modified. After tool check-out, body stamping production samples are run off and delivered for approval. Production of parts for inventory buildup may be initiated prior to full production which typically starts about one month prior to vehicle production.

7.2 LEAD TIME SCHEDULES FOR FRAMES

The automobile frame is the basic structure on which the body, engine, and axles plus most other systems are mounted. Equipment and techniques used for frame production are quite similar to those used to fabricate body stampings as discussed in the preceding section.

7.2.1 Normal Production Schedules for Frames

A typical frame production schedule indexed to the 1975 model year is shown in Figure 7-4. The activities are the same as those noted on the body stamping schedule. However, the overall frame lead time of

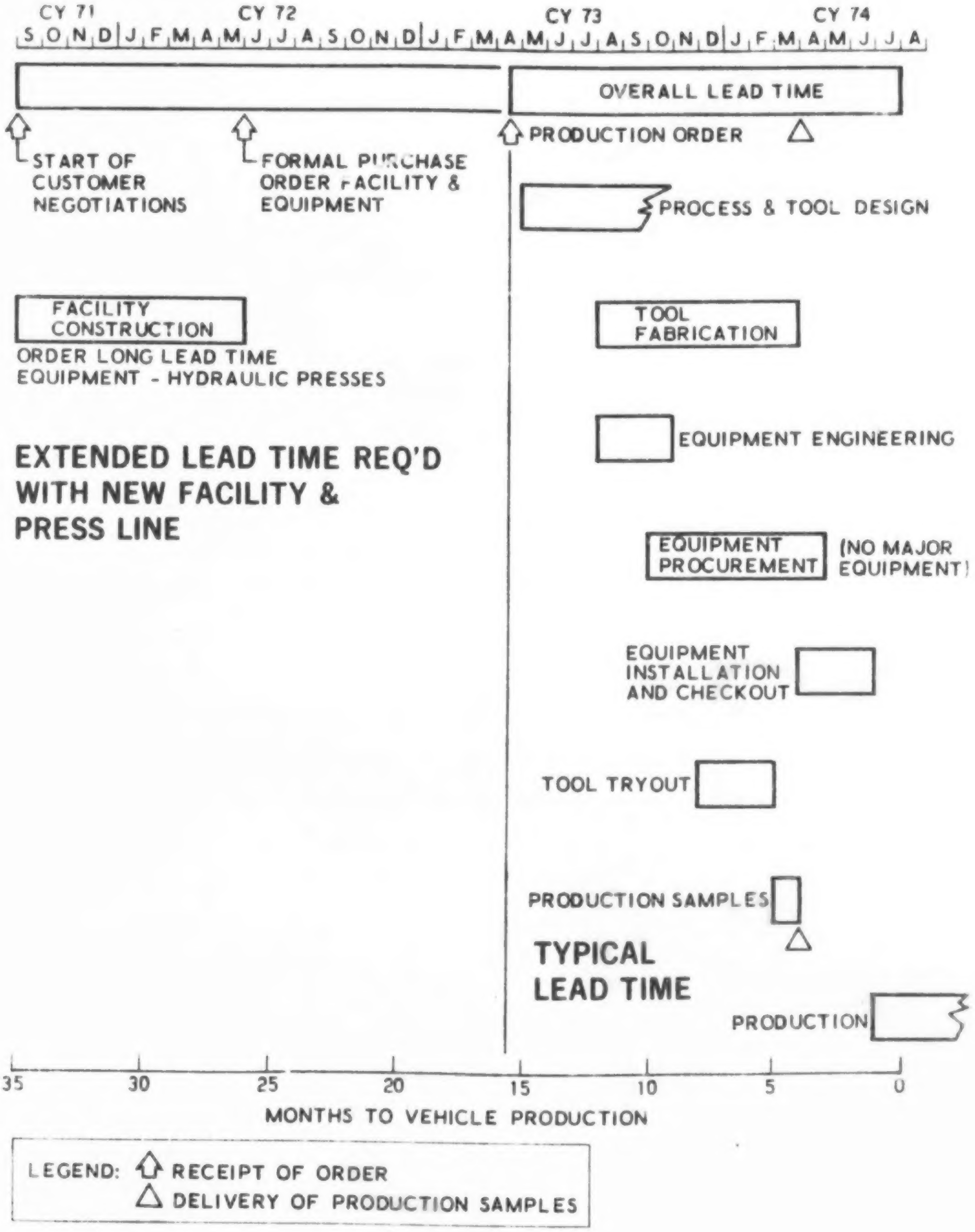


Figure 7-4. Frame Lead Time

15-1/2 months is 6-1/2 months less than that of the body stampings. This is because of the much smaller number of parts required for frame production.

7.2.2 Major Impact Factors for Frames

The same factors impact the frame schedule as those noted in the preceding body stamping discussion, i.e., possible requirement for new facilities or new capital equipment. The timing required for a new facility for frame production is noted on the left hand side of Figure 7-4, which is indexed to the 1975 model year, although the actual events are related to 1972 model year production.

For example, for the 1972 Ford Torino frame produced in Kitchener, Ontario, Canada, the size of the existing Budd plant had to be doubled. This facility construction is normally estimated to take three years from the time that a site is selected. Because of the availability of the site and duplication of the architecture of the original plant, four months were saved on this project. Nevertheless, a total of 35 months elapsed from the start of the negotiations in September 1968 until vehicle production. Although the formal purchase order was not signed until mid-1969, Budd had already contracted for facilities and large lead time equipment such as stamping presses prior to this date. Upon receipt of the Ford Motor Company engineering design concepts for the frame, engineering models were built by Budd in cooperation with the customer. Budd's contribution to design were confined mainly to manufacturing feasibility and cost cutting. Approximately 197 prototypes were built prior to and through the engineering phase from mid-1969 through mid-1970. These were forwarded to Ford for checkout purposes.

7.2.3 Critical Lead Time Items for Frames

As for body stampings, the critical lead time item in the frame schedule is tool design and fabrication, which is largely dies. Due to the much smaller number of dies involved, frame tooling time is about five months less than that for body stampings.

7.2.4 Major Elements in Frame Schedule

The major elements in the frame schedule are the same as in the preceding discussion of 7.1.4.

7.3 LEAD TIME SCHEDULES FOR TRANSMISSIONS

Automatic transmissions are produced at high production rates by the automobile manufacturers.[*] Transmissions manufactured at low production rates, such as manual transmissions, are the candidates for supply by a vendor, and, hence, are discussed in this section. These low production rates are on the order of 400 units per day.

7.3.1 Normal Production Schedules for Transmissions

As depicted in Figure 7-5, lead time is typically cited for repeat orders for a transmission that is currently in production. The pacing items are castings. If only gray iron castings are required, the overall lead time is six months from receipt of order to vehicle production. If the transmission contains either forgings or malleable iron castings, the overall lead time is 7-1/2 months.

Approximately once every five years, a transmission of new design is manufactured. In this case the normal overall time between receipt of order and vehicle production is 19.5 months. This is preceded by a development time period of two to six years.

The greatest compression possible on a normal production schedule for a new transmission is two months, resulting in a minimum overall production lead time of 17-1/2 months.

7.3.2 Major Impact Factors for Transmission Production

No major impact factors were identified for the normal schedule of a new transmission, assuming that facility expansion to provide more capacity is not required.

---

[*] Except for American Motors Corporation which purchases units from Chrysler Corporation.

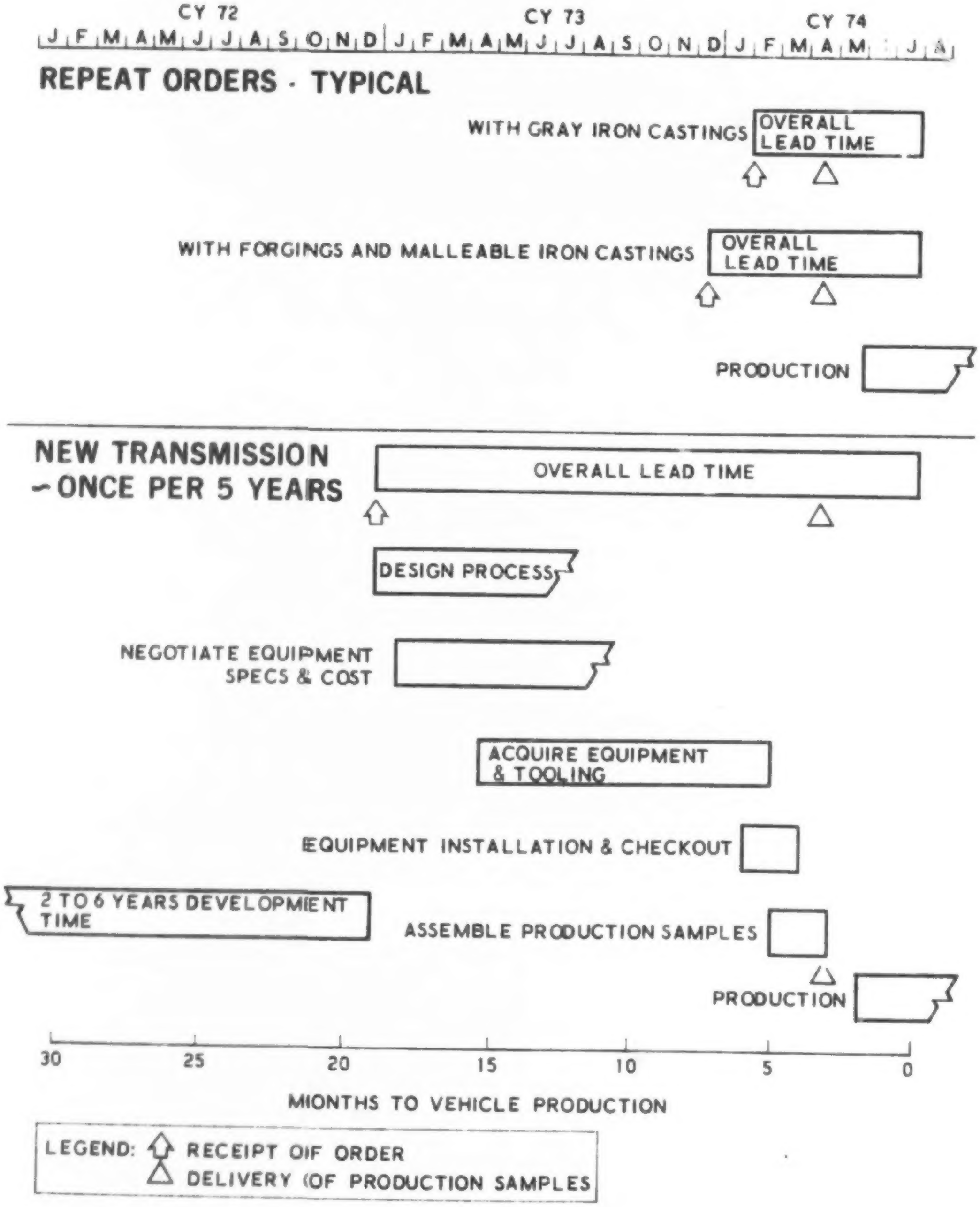


Figure 7-5. Transmission Lead Time

7.3.3 Critical Lead Time Items for Transmissions

The critical lead time items for production of a new transmission are the long lead equipment items to be used in the production line. These include automatic machining transfer lines (for machining the transmission case and the extension housing) and the more conventional machine tools such as milling machines, lathes and grinders. Besides the equipment acquisition time, the engineering time to negotiate specifications and the time to install and checkout the equipment are also critical. The overall critical lead time for equipment is about 15 months between engineering and the end of installation and checkout.

7.3.4 Major Elements in the Transmission Schedule

For a new transmission there is considerable development time involved between the concept and the first production order. The sequence begins with the definition of the concept by either the customer or the vendor. A concept layout is prepared by the vendor for customer acceptance. After acceptance, the vendor's engineering department prepares shop drawings and the cost analysis is refined (three to eight months). These drawings are then submitted to the customer. At this point the vendor would normally receive an order for a pilot lot of prototype units, around 25. Preliminary tooling is designed and fabricated, some of which may be used later in production. The pilot lot of transmissions is delivered to the customer for his testing. The above activities usually take 20 to 24 months for a new design. For a minor modification to an existing design about six months is required. The customer then tests the prototype transmission and the design is refined. The time required for this test activity is highly variable ranging from three months to four years. The final piece-part cost for the refined design is prepared by the vendor and quoted to the customer for the production order. No engineering or purchasing for production is done until receipt of the production order. The above development time would require two to six years depending on customer testing time, however, the six years would seem unusual. Perhaps 30 months would be reasonably representative of the development time.

Upon receipt of the production order, refining of the process design for the transmission production line is initiated. The emphasis is to first complete the process design that relates to the long lead equipment items so that equipment specifications can be negotiated as soon as possible. Once the equipment is specified it is placed on order, followed by orders for tooling, piece parts and raw material.

As the equipment is received it is installed and checked out. Transmission piece parts together with production samples of purchase piece parts are used to assemble the lot of transmission production samples for delivery to the customer for approval.

In order to compress the schedule by two months, as in the case of the 1974 model year Pinto four-speed manual transmission, two steps are being taken. The first step was to have Ford assist in negotiations with long lead time equipment vendors, so that equipment specification time was reduced. The second step was to plan means for assembly of the transmission production samples while installation and checkout of the line is being conducted. This will be accomplished by the equipment manufacturer using tryout piece parts furnished by the transmission manufacturer for final checkout of equipment prior to shipment.

7.4 LEAD TIME SCHEDULES FOR CARBURETORS

In the production of carburetors the manufacturer makes all critical functional parts and stampings, and machines the piece parts and die castings; the carburetor is then assembled and tested. (Rotary indexing machines are used in many machining operations for transferring the part between machining stations.) Die castings, gaskets, fasteners, formed tubing, rubber goods and other specialized items are normally purchased from suppliers.

7.4.1 Normal Production Schedules for Carburetors

Normal schedules for a new 1975 carburetor (with its associated development time) and for a previously developed carburetor of known design and production experience are shown in Figure 7-6. The overall production lead time for a new carburetor is 18 months between receipt of order and vehicle production, and is 12-1/2 months for a carburetor of proven design. The reasons for the 5-1/2 months of additional time appear to be the greater time required to build dies to produce die castings for a new carburetor, time to acquire equipment and tooling (including flow check equipment for calibration functional tests), and the additional contingency time for equipment installation and checkout. The necessity for the contingency time is illustrated by a vendor's production experience with a carburetor (incorporating a pressure tap for control of engine exhaust gas recirculation) which was being produced with an 80% reject rate.

For a proven carburetor it was estimated that the schedule might be compressed about one month by compression of tool design and build periods and by compression of equipment installation and checkout periods. This would result in an overall lead time of 11-1/2 months.

For an unknown, or new carburetor there may be a potential for schedule compression. Much depends on the degree of financial risk the carburetor vendor is willing to assume. A new carburetor on a crash program entails the possibility that engineering and purchasing funds expended for a given initial design will be lost through later changes.

7.4.2 Major Impact Factors for Carburetors

Assuming that facility expansion would not be required, the major impact factor cited was product design, which impacts as discussed in Section 7.4.1.

7.4.3 Critical Lead Time Items for Carburetor

The items in the critical path of a carburetor schedule are tooling design, tooling fabrication, and installation and checkout of the production line equipment, which are all carburetor manufacturer activities.

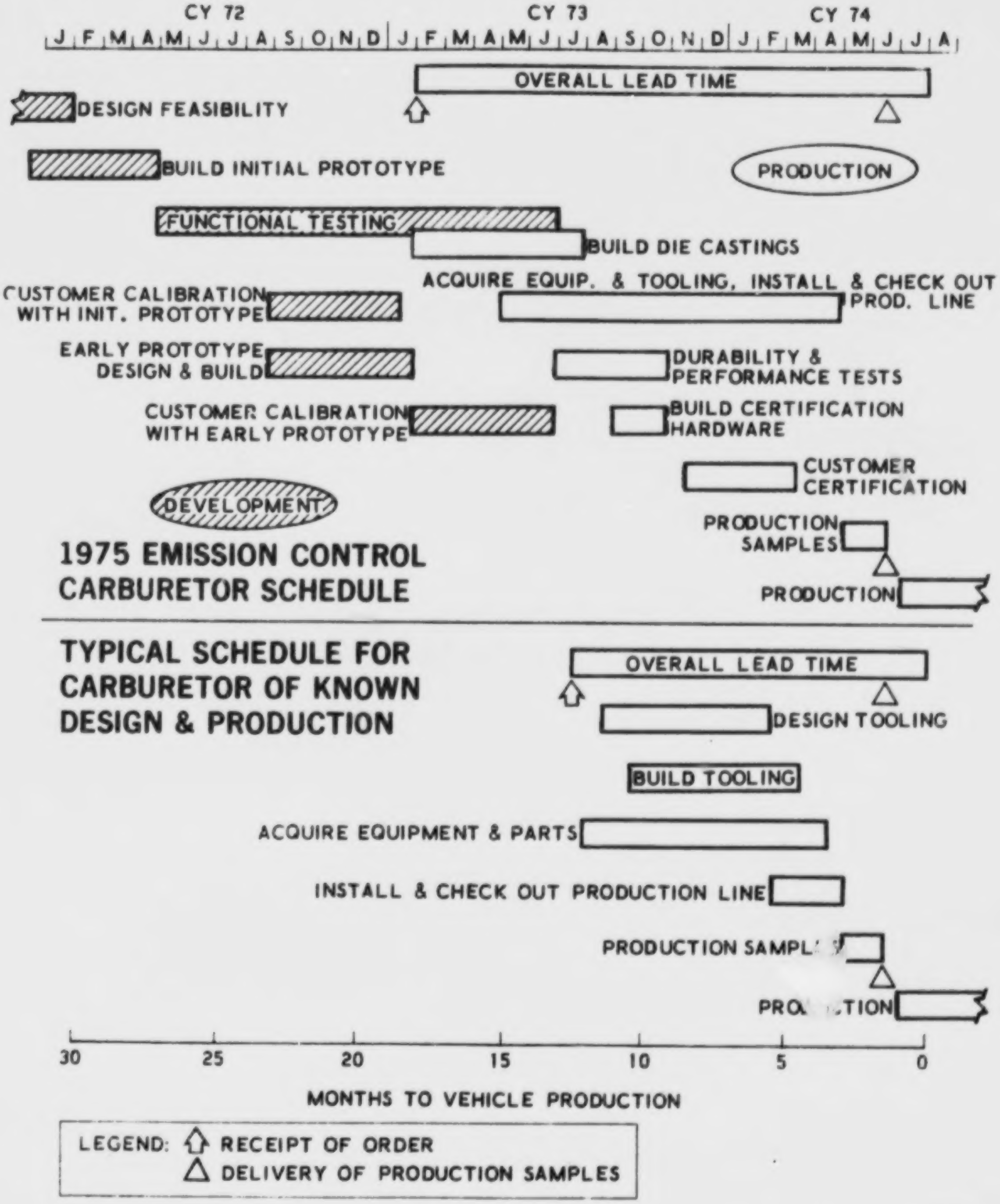


Figure 7-6. Carburetor Lead Time

7.4.4 Major Elements in Carburetor Schedule

Although not in the production lead time per se, the development activities for a new carburetor influence the production lead time. The development time begins with design feasibility as noted on Figure 7-6.

The carburetor manufacturer's advanced engineering department performs design feasibility work and an initial lot of prototypes are built and furnished to the customer who tests the carburetors on the prototype engine. It is an iterative process where test results are fed back to the carburetor manufacturer and carburetor modifications are made or new prototypes are built and further testing is performed on the engine. As the carburetor design is refined, early production prototypes of the anticipated design are furnished to the customer for calibration with the engine. The nature of the development activity gives the carburetor manufacturer a good understanding of potential problems that may be encountered during the actual production and tends to decrease the lead time. Then the carburetor manufacturer prepares a quotation based on customer furnished production delivery dates and production rate.

The first activity after receipt of the production order for a new carburetor is to release an order to a castings supplier to build the dies and supply castings. The major items of equipment are then specified, the tooling is designed, the orders are released for equipment, and tooling fabrication is begun. Concurrently, as die cast samples are received, prototype carburetors are fabricated and assembled for durability and performance tests by the carburetor manufacturer. When final die castings are received, the "certification carburetors" are fabricated and assembled and furnished to the customer for certification testing. As the production line equipment and tooling is received it is installed and checked out. Upon completion of this effort, the lot of production samples is built and furnished to the customer.

The activities for a known carburetor are similar except the die casting dies exist and the testing for durability, performance, and certification is not required.

7.5 LEAD TIME SCHEDULE FOR EXHAUST SYSTEMS

The lead time schedules for exhaust systems are shown on Figure 7-7. The normal overall lead time for a conventional exhaust system is six months, with tooling design and fabrication being the pacing item. For a new exhaust system with a resistance welded stainless steel canister the overall lead time between receipt of order and vehicle production is nine months.

Both of the above normal schedules assume that production line equipment is available and that tooling is the critical item.

If new major production equipment should be required, the overall lead time might be as much as 18 months. Based on the timing of production line elements discussed in previous sections, an estimate of the major schedule activities for process design, equipment specification negotiation, equipment acquisition and installation and checkout for a new metal forming line has been made as shown on Figure 7-7.

7.6 LEAD TIME SCHEDULES FOR WHEELS AND BRAKE PARTS

The overall lead times between receipt of order and vehicle production for wheels and brake parts are depicted on Figure 7-8 and tabulated below.

	Overall Lead Times (Months)	
Item	Tooling Critical	Equipment Critical
Wheels	10	14
Hubs	14	14
Discs	14	14
Brake Cylinder	10	14
Disc Brake Caliper, Defined	10	--
Disc Brake Caliper, New Design	--	19

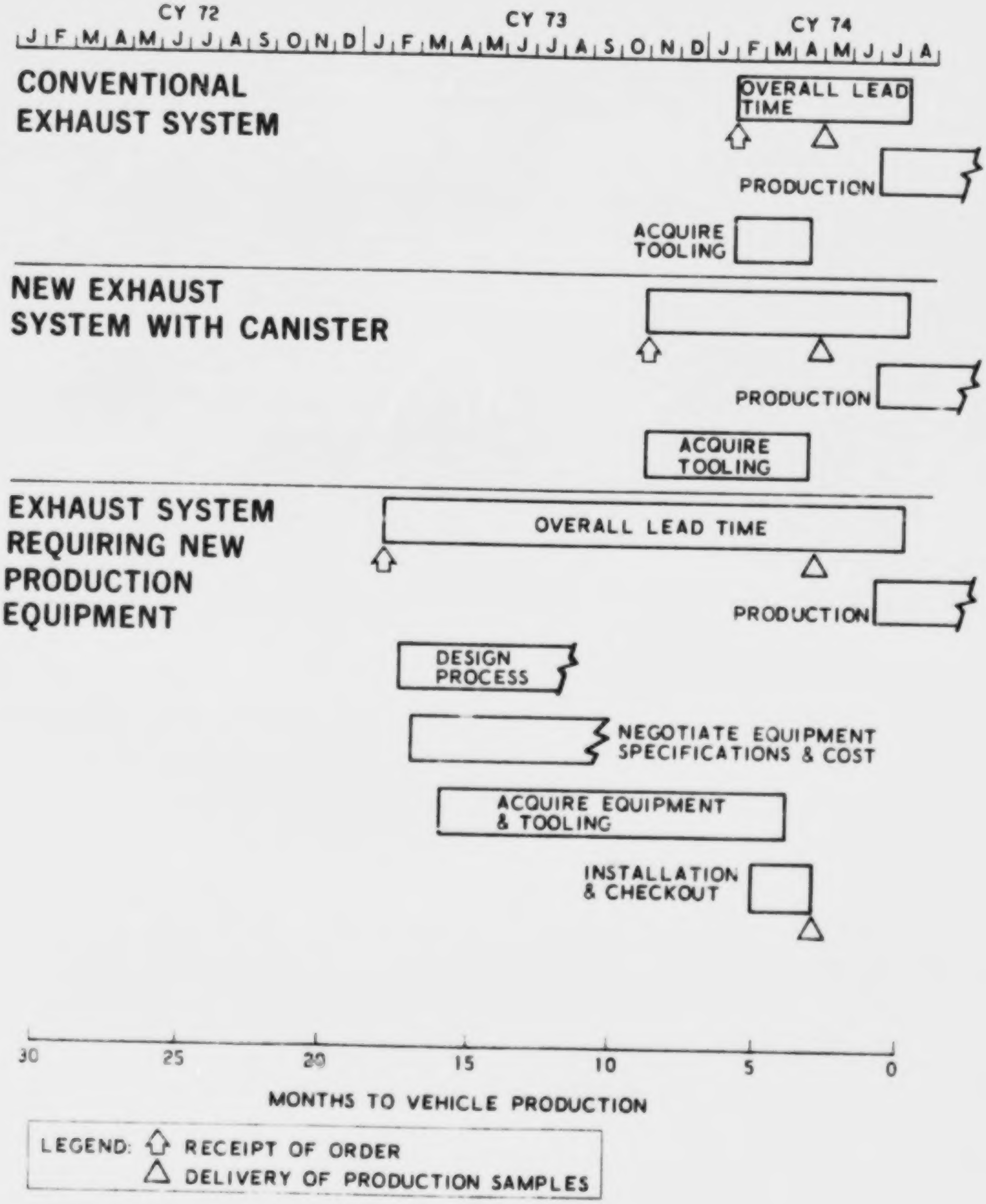


Figure 7-7. Exhaust System Lead Time

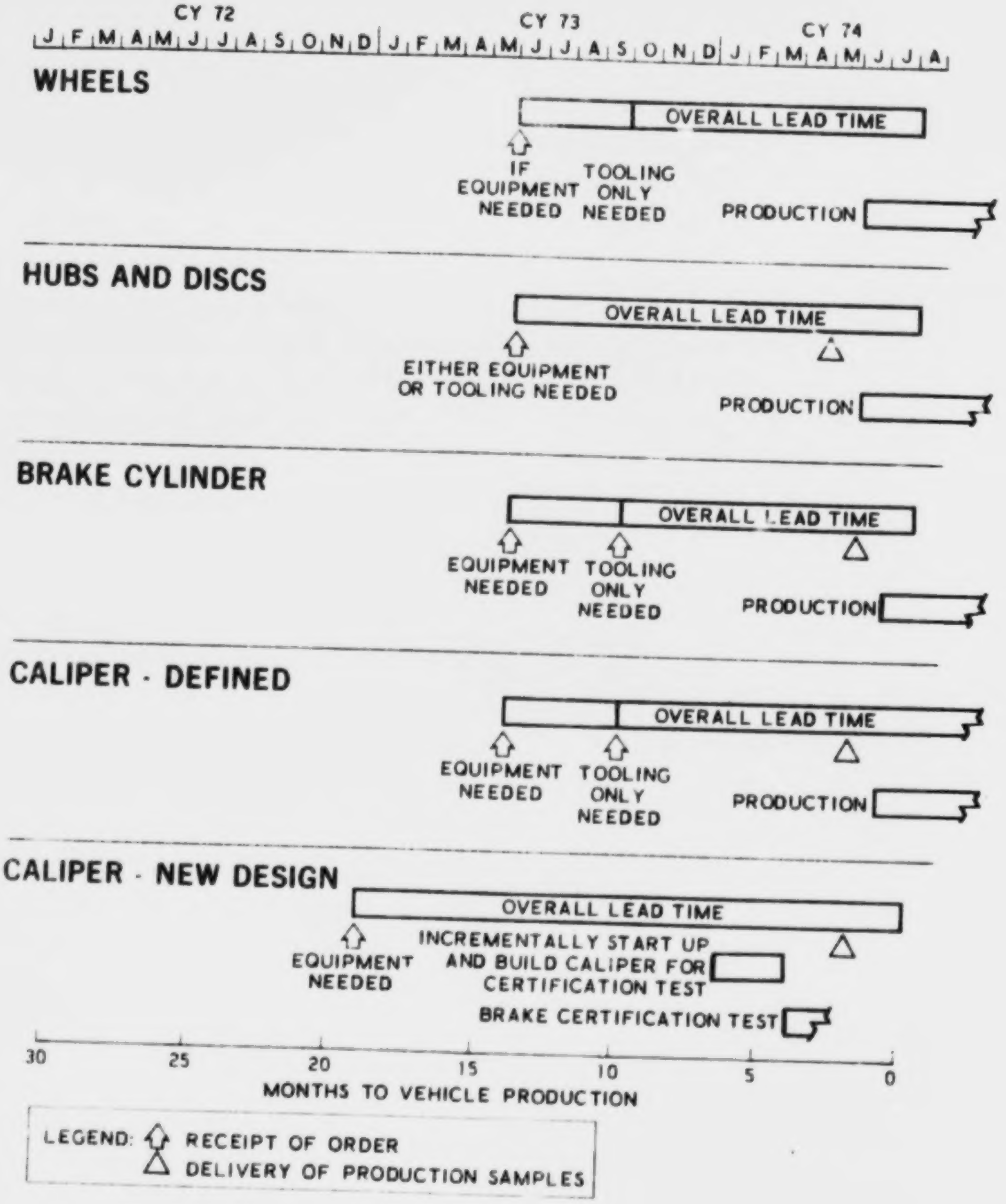


Figure 7-8. Wheels and Brake Parts Lead Time

7.6.1 Major Impact Factors for Wheels and Brake Parts

The factor cited as having a lead time impact was the regulations of the National Highway Traffic Safety Act. As noted on Figure 7-8, this required additional time to conduct the brake certification tests which added five months to a schedule where equipment is required for a new production line.

7.6.2 Critical Lead Time Items for Wheels and Brake Parts

The pacing items that determine the lead times are either tooling or new equipment for a new production line as noted on Figure 7-8. The times required between receipt of order by the wheel or brake part manufacturer and delivery of production samples from the new line is tabulated below, for the situation where the equipment designated is pacing the schedule.

Equipment	Time From Order to Production Samples (Months)
Bullard, (8) Spindle Type "L" Machine	9-10
Motch/Merrywheather Transfer Machine	12
Assembly Transfer Machine	8-10
Vertical Lathes	6-8
Multispindle Drill	5
Grinder, Disc Brake	8
Washer, Transfer Type/ Multistage	6
Rim Line	12
Welders, Submerged Arc	6-8
Presses, 250 Ton	8
Cincinnati Hydrospin	10
Trimming Lathe	8
Assembly Machine, Hydraulic	6
Paint System	5-6

7.7 LEAD TIME FOR OTHER COMPONENTS

The normal lead time for other components of the automobile, such as valves and window assemblies, are shown in Figure 7-9. Ordinarily, existing production equipment is adequate and obtaining new tooling is the critical lead time item. Where a range of lead time is indicated, the variation is due to complexity of the tooling resulting from different parts design.

7.7.1 Major Impact Factors for Other Components

The major impact factors identified are product design, production rate and foundry capacity in the instance of castings.

If the product is of a type and size range that has been built before, its lead times are minimum and are paced by its tooling lead times as noted above. However, if new equipment is required by the design of the product, the lead time may be increased, depending on the type and quantity of equipment needed. This is indicated by the timing shown for a radiator fan on Figure 7-9 where the overall lead time is 14 months for a fan built from a new production line as contrasted with a period of 8 months for a fan built from an existing production line.

If the production rate is significantly higher, a new facility becomes necessary, which has the most significant lead time impact. Figure 7-10 indicates the key events and their timing for a new facility for engine valve production. As was done for the other figures, it is set in the 1975 model year time frame for ready comparison. Approval of the appropriation request is shown as the main starting point since it represents the management decision to commit resources for production. In the seven months preceding that point, however, the site location is selected and orders for the hot forging presses (critical pacing item) are placed with a no charge cancellation clause. The press orders are made firm upon the approval of the appropriation request and other equipment is ordered. Partial production begins, using purchased forgings prior to receipt of the hot forging presses.

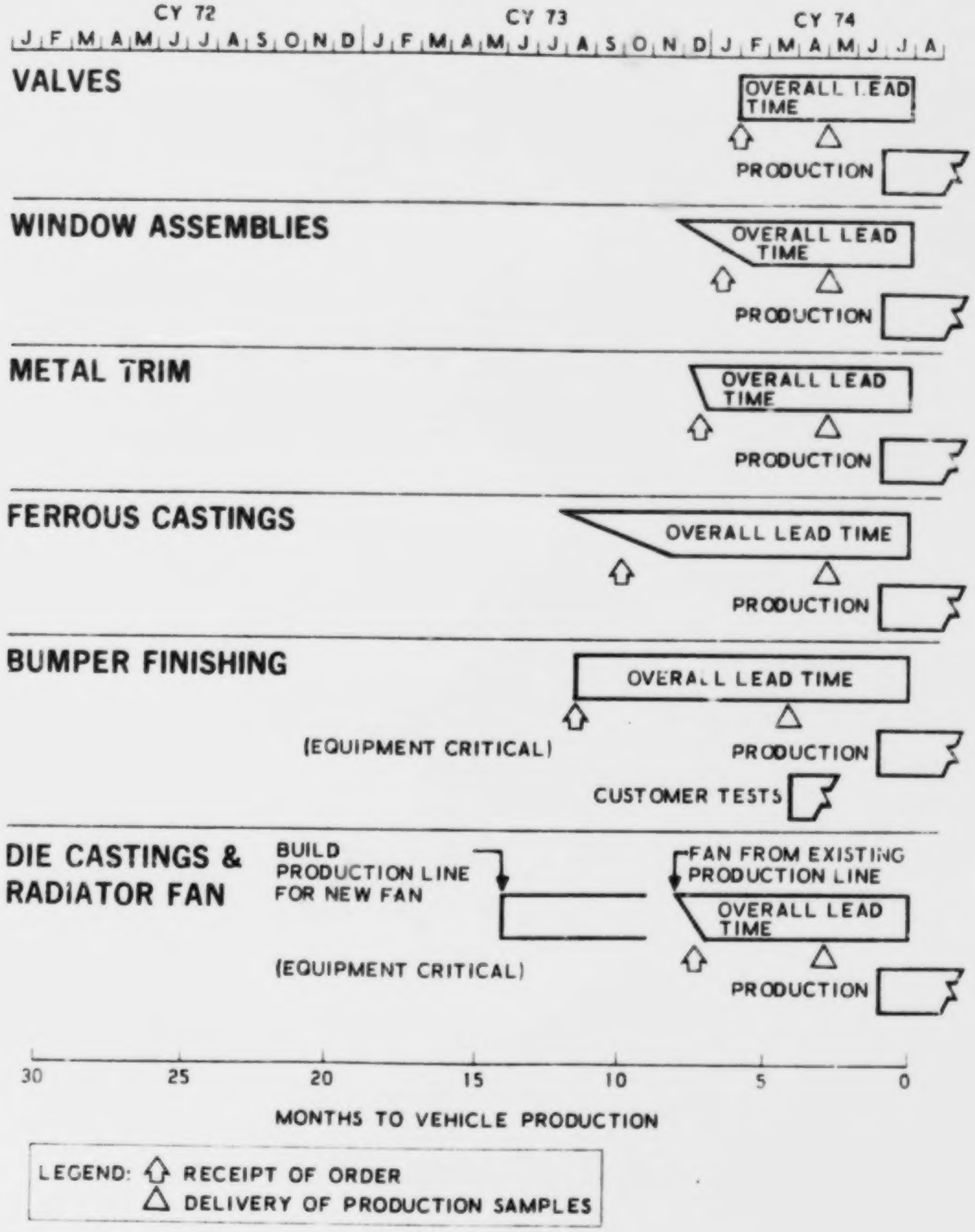


Figure 7-9. Other Components Lead Time (Tooling is Critical Item Unless Noted Otherwise)

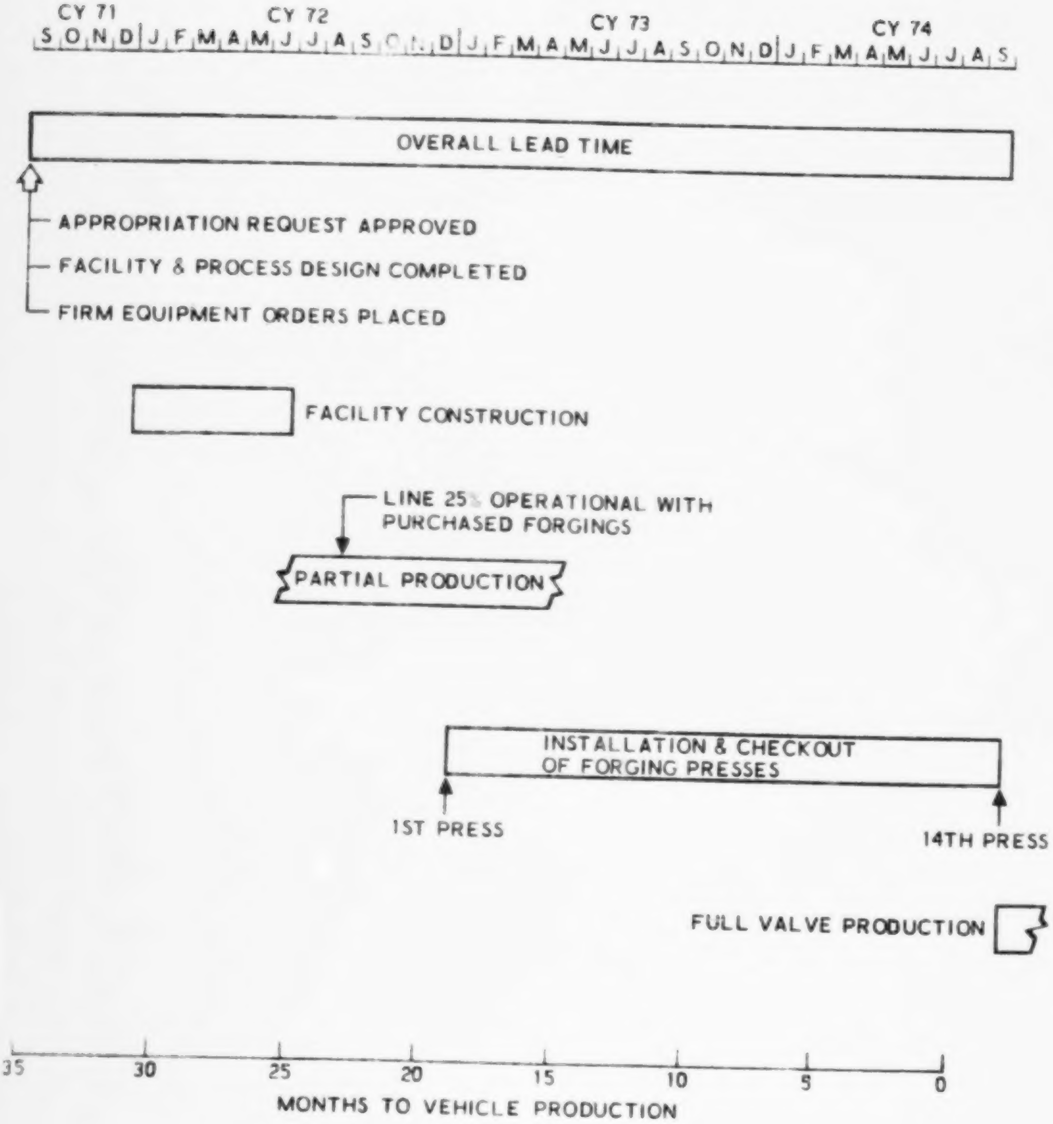


Figure 7-10. New Engine Valve Facility Lead Time

The line required 14 forging presses which took about 21 months from delivery of the first press until installation and checkout of the last press. The line was producing at full production rate at the end of September in the year prior to the model year. The lead time for procurement of presses is very dependent on the business state of the hot forging press suppliers. If they are in slack times one press could be delivered in 15 months. If they are heavily back ordered, the first press might require 36 months lead time.

If additional foundry capacity for ferrous castings is required, 36 months is required to bring it to full production status. However, there is a reluctance in the industry to invest in new foundry capacity since profitability is less due to price controls and there are energy supply uncertainties. Total industry foundry capacity may be critical with some uncertainty about the ability to supply future requirements.

SECTION 8

LEAD TIME SCHEDULES FOR PRODUCTION EQUIPMENT MANUFACTURERS

This section presents normal production schedules, major impact factors, and critical lead time items and discusses major elements of the schedules for production equipment manufacturers. Lead time data based on both recent and current industry experience were obtained from various manufacturers. However, for ease of comparison the data are presented in the 1975 model year time frame. Presented in Figure 8-1 are summary lead times for major items of automobile production line equipment from receipt of order to Vehicle Job No. 1. The times shown are for single units; however, the discussion on welders covers the lead time impact when more than one unit is ordered.

8.1 LEAD TIME SCHEDULES FOR AUTOMATIC TRANSFER LINES

For this report the term automatic transfer line has been adopted as a generic term for equipment that performs automatic machining or assembly operations. Transfer lines are used for automated machining of a wide variety of automotive piece parts, with the engine block and head machining lines being among the more notable examples. Figure 8-2 illustrates the sections of an engine block machining transfer line and the various machining operations performed. Another transfer line application is the automatic assembly of automobile bodies.

8.1.1 Normal Production Schedules for Automatic Transfer Lines

Figure 8-3 provides several illustrations of lead time associated with automatic transfer lines. Depending on the complexity and size of the

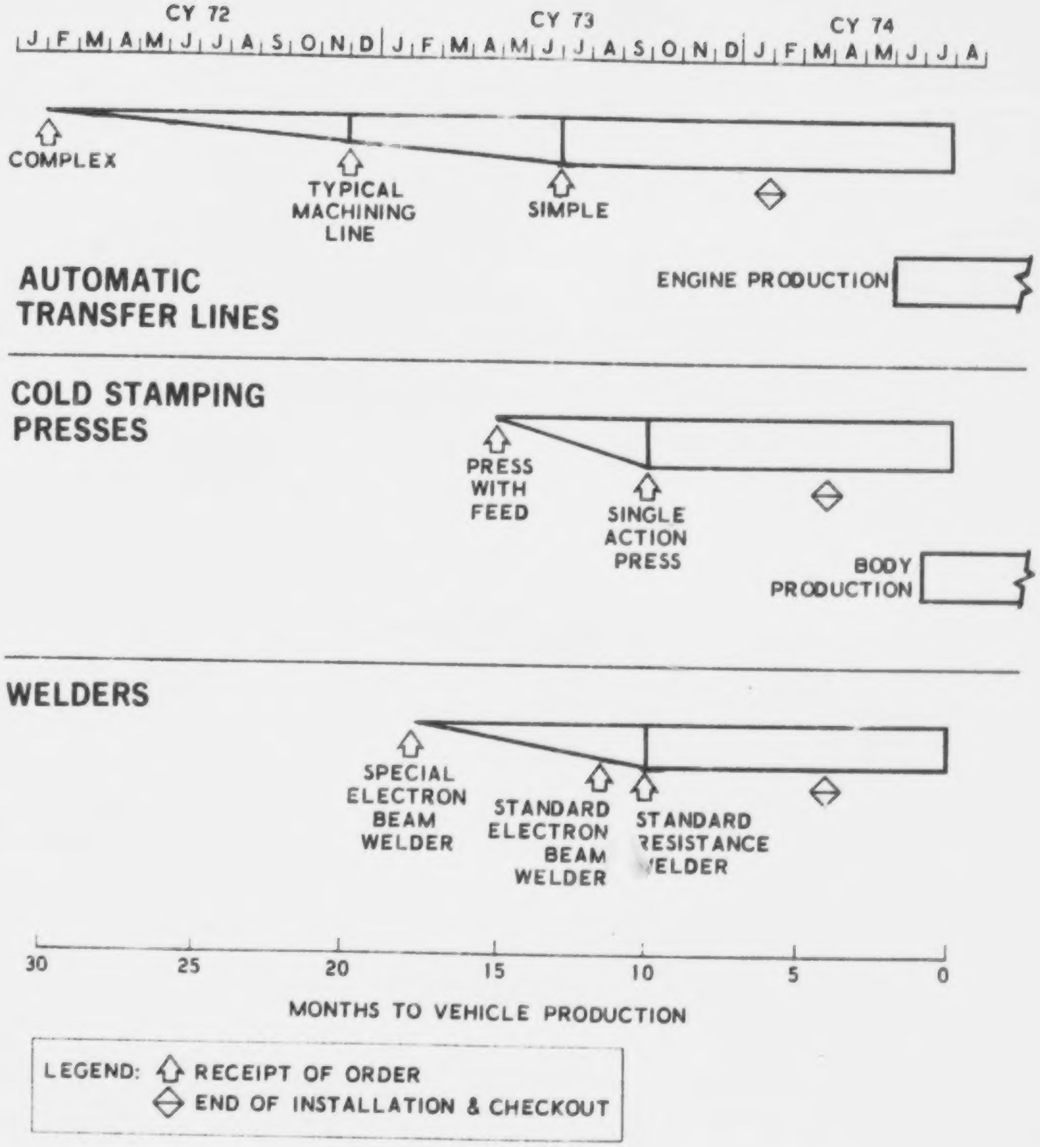


Figure 8-1. Production Equipment Manufacturers' Overall Lead Time

Cylinder Block

A brief description of the major machine sections follows.

1) Mill and broach locating notches.
2) Rough mill trans. notches, brg. half rd., oil pump mtg. face, brg. cap seats, pan rail and fin. mill brg. cap seats.
3) Rough mill rear face, left bank, right bank and front face, finish mill top rails, fuel pump mtg. pad and front face.
4) Mill brg. lock notches, rough mill rear crank brg., finish mill motor mounting pads, crank brg. side faces and inner-crank brg. side faces.
5) Semi finish cylinder bores.
6) Drill and tap front and rear.
7) Drill pan rail.
8) Drill and tap pan rail sides and angular front holes.
9) Drill right and left banks.
10) Drill and ream tappet holes, tap bank and misc. holes.
11) Finish cylinder bores.
12) Semi finish cam and crank bores.
13) Press in cam brg. shell.
14) Finish cam and crank bores.
15) Finish mill bank and rear faces.

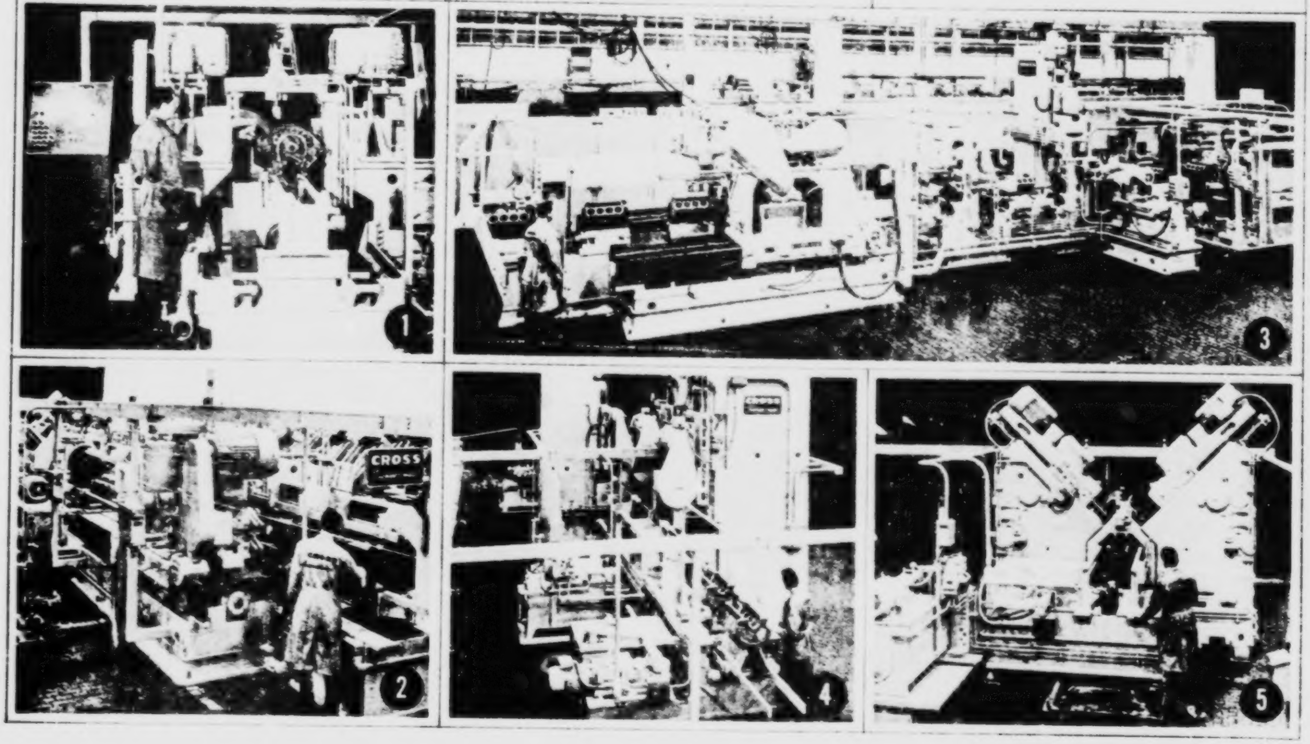


Figure 8-2. Engine Block Machine Transfer Line

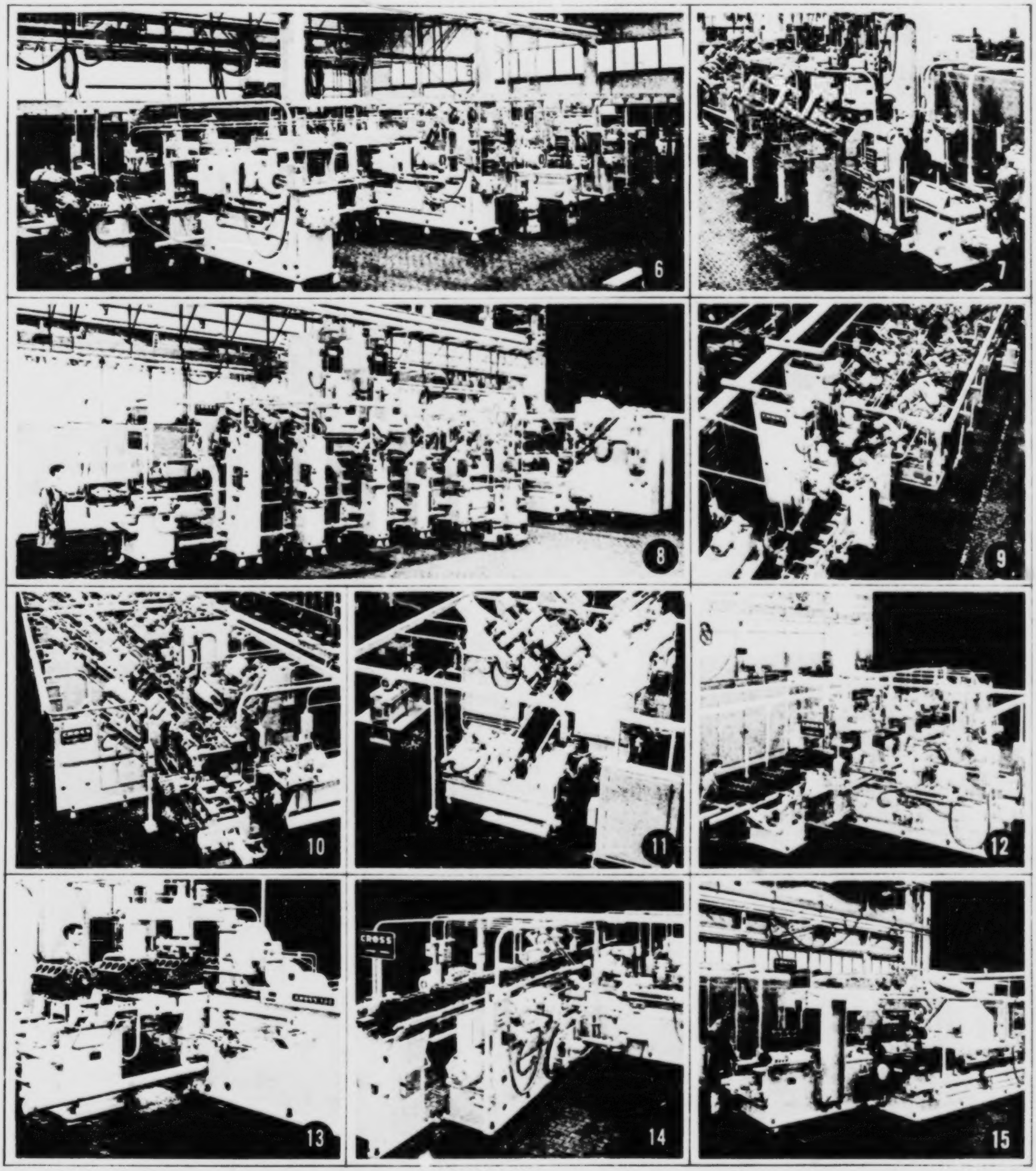

6
7
8
9
10
11
12
13
CROSS
14
15

Figure 8-2. Engine Block Machine Transfer Line

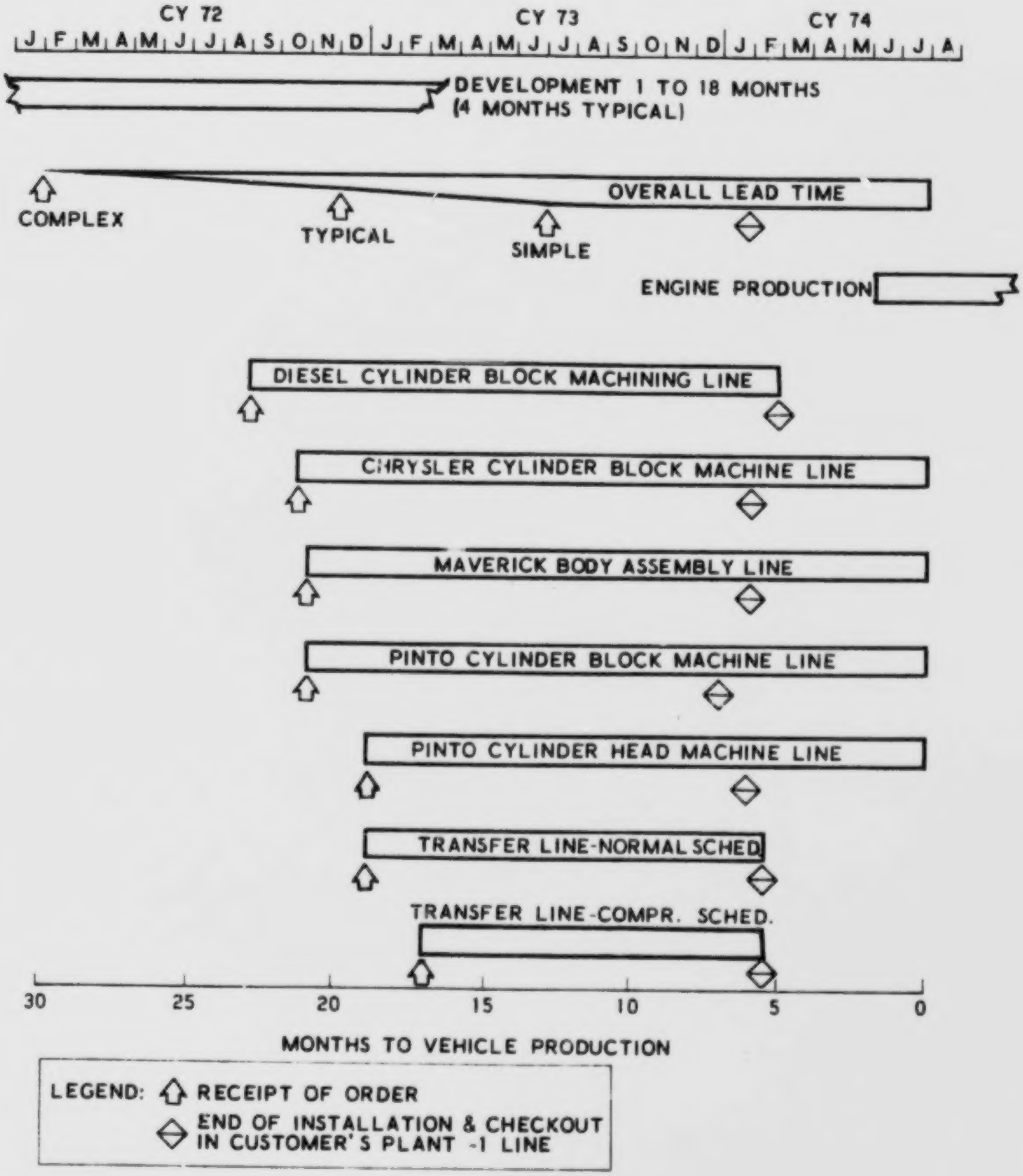


Figure 8-3. Automatic Transfer Line Lead Time

transfer line the overall production lead time between receipt of order and vehicle production can range from 13 to 30 months. A typical lead time for a transfer line is considered to be about 20 months based on the case histories noted in Figure 8-3.

The bottom two schedule bars in Figure 8-3 are based on data furnished by a manufacturer as being typical of schedules quoted to the automotive industry for a transfer line costing about $1 million. Assuming no piece-part changes and plant capacity is available, it might be compressed about two months at no cost increase.

8.1.2 Major Impact Factors for Automatic Transfer Lines

The major impact factors identified were product design and business conditions. It was implicit that facility expansion of the transfer line manufacturer is accomplished in accordance with sales forecasting where continuous future use of the new facility might be expected.

The lead time requirement is based on the available plant and engineering capacity of the transfer line manufacturer and on the type of design of the transfer line. A simple, small machine requires little engineering or shop time, whereas a complex transfer line several hundred feet long requires significant amounts of engineering, fabrication and assembly time.

Business conditions impact lead time in the form of number of orders placed by the automobile manufacturers. The backlog of orders is a measure of plant and engineering capacity already committed. Therefore any new orders will be delayed in implementation until they can be accommodated within the manufacturer's capacity.

8.1.3 Critical Lead Time Items for Automatic Transfer Lines

As can be inferred from the above discussion, the critical lead time item is the transfer line manufacturer's available plant and engineering capacity; the available engineering capacity is the most critical. While portions of the shop work can be subcontracted for schedule control purposes, this is impractical for the engineering work. Standard practice during periods with order backlogs is to work 50 to 55 hours per week in the engineering departments, so there appears to be little expansion potential for engineering overtime.

8.1.4 Major Elements in Automatic Transfer Line Schedules

Figure 8-4 presents the major elements of a transfer line manufacturer's schedule for a multisection cylinder head machining line. It is noted that the job is processed in series beginning with the first section of the line. The initial activity is engineering on the first section where the long lead purchase items (e.g. precision bearings - up to five months, bar stock for the main transfer bar - four months) are identified early and released for purchasing. Castings are designed and drawings are released to the shop at an early date. Engineering is then completed on the less critical items and released. Prior to completion of all engineering on the first section, engineering is initiated on the second section in a similar manner. About 8-1/2 months of total engineering time is required for all 14 sections.

Purchasing and parts fabrication by the shop are also done in series on the sections, so that the sections flow through the assembly floor in the same manner. Each section is completely assembled and checked out prior to shipment. Usual practice is to run a section with castings furnished by the customer and the machining operations are checked by the customer's gaging and inspection equipment. The checkout operation is witnessed by the customer and his approval is necessary before shipping.

The section is then torn down to the shipping configuration, crated and shipped. At the customer's plant, it is reassembled, installed and checked out. The time between receipt of order and the end of installation and checkout of the last section is 14 months for a typical overall lead time of 20 months from receipt of order to vehicle production.

8.2 LEAD TIME SCHEDULES FOR COLD STAMPING PRESSES

Cold stamping presses are used for production of automobile bodies and frames and for many other sheet metal forming operations.

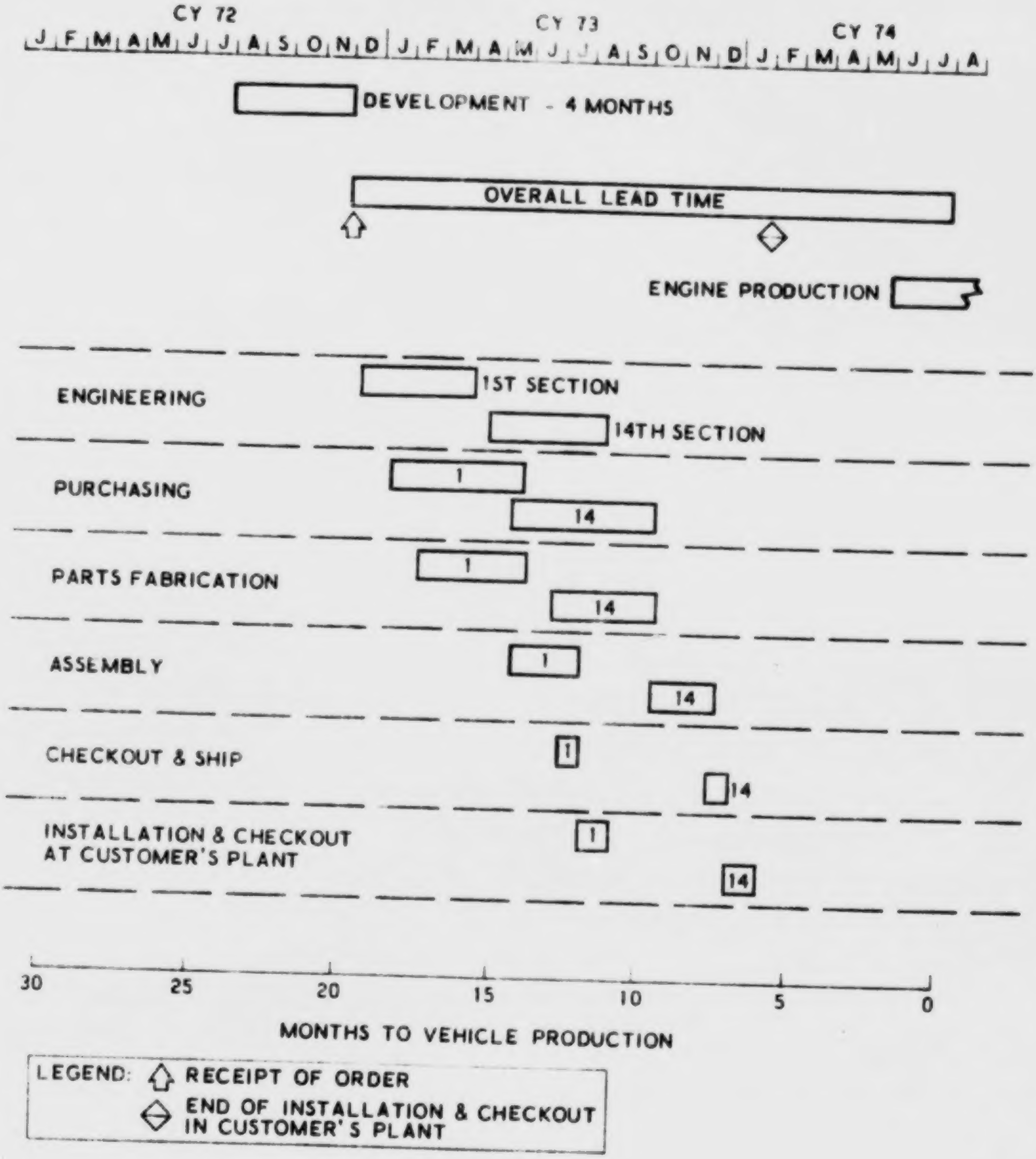


Figure 8-4. Transfer Line - Representative Lead Time (Cylinder Head Machining)

Press types (single action, double action, triple action; overdrive or underdrive) and capacities (500 to 4000 tons) are variable. Figure 8-5 e illustrates an underdrive press (drive mechanism located underfloor as opposed to location on top of the press).

8.2.1 Normal Production Schedules for Cold Stamping Presses

The overall lead time for one press ranges from 10 to 15 months depending on the type of press, the differences in the design from an existing design, and the optional feed or drives that may be selected. The following table presents the overall lead times from receipt of order to vehicle production for the different presses.

Type of Press		Overall Lead Time Months
Triple Action Presses	- Near Duplicate	12 to 13-1/2
	- New Design	13 to 13-1/2
Double Action Presses	- Near Duplicate	11-1/2 to 13-1/2
	- New Design	13 to 13-1/2
Overdrive Presses	- Near Duplicate	10 to 11-1/2
	- New Design	10-1/2 to 11-1/2
Synchromatic Press Lines	- Near Duplicate	12-1/2 to 13
	- New Design	13-1/2 to 14
Optional Press Feed		13-1/2 to 15
Optional Press Drive		13 to 14
Optional Dynamatic Drive		12 to 13-1/2

The range of time for any individual press depends on critical lead time elements of the press which are detailed in a later section.

8.2.2 Major Impact Factors for Cold Stamping Presses

The lead times given in Section 8.2.1 are for one press. If a large number of orders are received in a short period, the lead times will

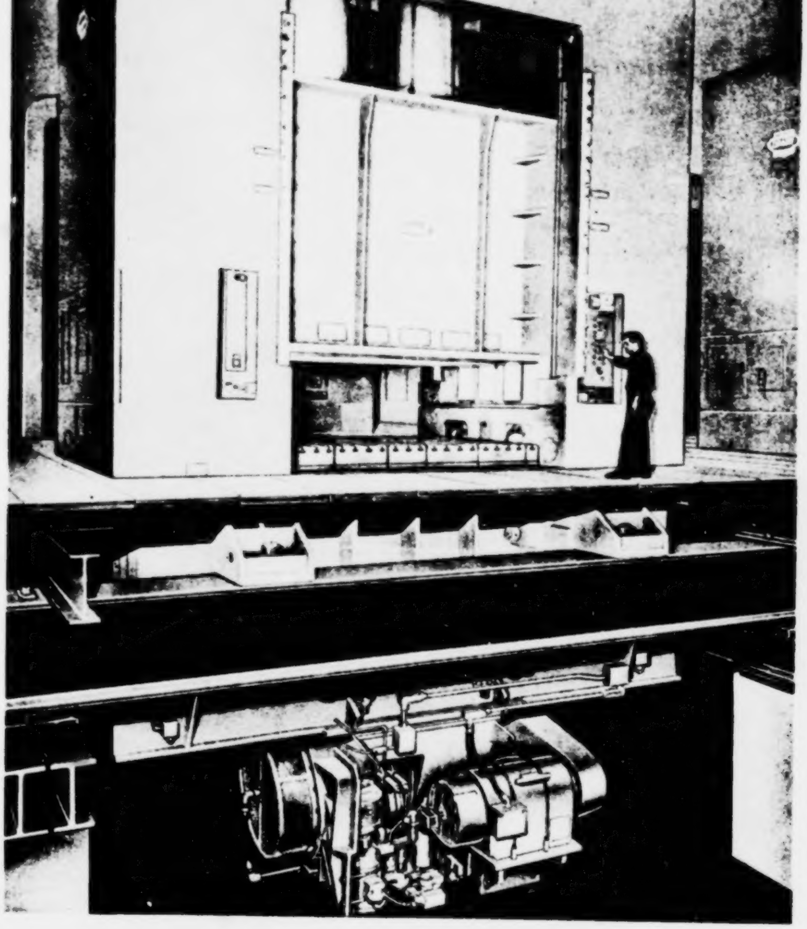


Figure 8-5. Underdrive Press

have to be extended, although subcontracting can be employed to limit the extension. A case in point is when Ford, General Motors Corporation, and Chrysler Corporation were all building new plants in the 1955/56 period and a press manufacturer had contracts for about 60 presses. To meet schedule, subcontracts were issued to 17 companies to build presses.

8.2.3 Critical Lead Time for Cold Stamping Presses

The lead time for presses is paced by fabrication of various parts used in the press construction such as drive controls. The times required for the various parts are tabulated below in weeks. The Engineering Time is that required to select and specify a purchase part for buy items or, in the case of parts fabricated by the press manufacturer, the time to produce shop drawings. The Vendor Time is the time between engineering release of a purchase part to receipt of the part. The Press Manufacturer's Fabrication Time is the time from engineering release of shop drawings to the point where parts are ready for assembly, and includes raw material procurement time. Total Time is the sum of Engineering Time and the appropriate Vendor or Press Manufacturer Fabrication Time.

Press Critical Item Lead Times in Weeks

Item	Engr. Time	Vendor Time	Press Mfr. Fabrication Time	Total Time
Press Feeds	4	28 to 32	--	32 to 36
Press Drive Controls	9	20 to 24	--	29 to 33
Main Weldments	7 to 9	--	9 to 23	16 to 32
Crankshaft Forgings	4 to 6	18 to 25	--	22 to 31
Dynamatic Press Drives	1	25 to 30	--	26 to 31
Main Weldments-Purchase	7 to 9	--	14 to 21	21 to 30
Tie Rod Forgings-Purchase	3	20 to 26	--	23 to 29
Bearings	3	8 to 26	--	11 to 29

Item	Engr. Time	Vendor Time	Press Mfr. Fabrication Time	Total Time
Fabricated Gears	1 to 4	--	13 to 20	14 to 24
Finished Gears	1 to 3	14 to 20	--	15 to 23
Drive Motors	3	13 to 20	--	16 to 23
Iron and Steel Castings	4	--	12 to 18	16 to 22
Tie Rod Forgings	3	--	14 to 16	17 to 19
Tie Rods - Hot Rolled	3	--	10 to 14	13 to 17

8.2.4 Major Elements in Cold Stamping Press Schedules

The major elements in the design and manufacture of a cold stamping press are indicated in the lower portion of Figure 8-6 for a triple action press of new design. The upper portion indicates the range of normal lead times discussed earlier.

The major elements and the activities undergone are quite similar to the discussion for transfer lines in Section 8.1.4. However, it may be instructive to detail the activities for the Main Weldment, which is the overall press frame, as it flows through the press manufacturer. After the job enters engineering, the product design engineering department carries the whole press design to the point where the Main Weldment design can be transferred to manufacturing engineering for preparation of welding detail drawings. Once the weld details are completed, the drawings are released to the shop and the raw material is ordered. If material is in stock there is no lag time. If not in stock, up to eight weeks are required to receive the material.

Depending on the size of the press, some of the main weldment pieces are fabricated from 14-inch thick steel plate which is a

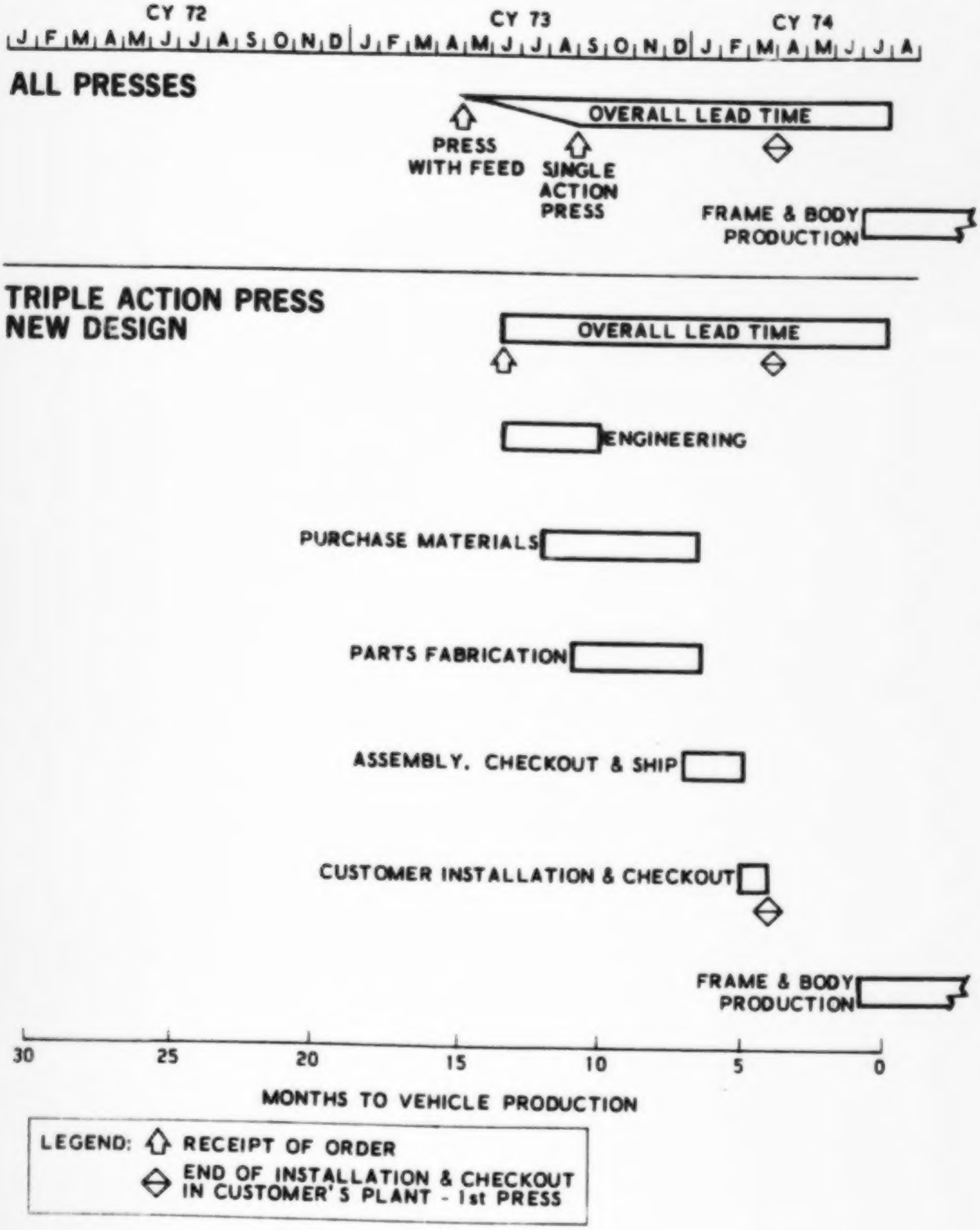


Figure 8-6. Cold Stamping Press Lead Time

special mill order. The time to weld the Main Weldment is five to ten weeks. The welding operations include the following:

- a. Torch cut detail piece
- b. Machine details
- c. Weld set up
- d. Welding
- e. Stress relieving
- f. Shot blast
- g. Snagging (clean up with grinder)

The main weldment then goes through the machining operations which requires four to five weeks. These operations include the following:

- a. Layout and inspection (repair welds, add stock as required; lay out reference lines for subsequent machining)
- b. Paint
- c. Machining operations - typically:
  - 1. Milling
  - 2. Planing
  - 3. Boring
  - 4. Drilling
- d. Final Inspection

The Main Weldment is then sent to the assembly floor. During the next four to six weeks the entire press is assembled, tried out, disassembled, and prepared for shipment.

8.3 LEAD TIME SCHEDULES FOR WELDERS

Resistance welding is generally used in the assembly of light gage materials and can be used to spot weld, seam weld, or lap weld. Most conventional automobile assemblies are resistance welded using spot welding. Arc welding [metal-inert gas (MIG) or tungsten-arc inert gas (TIG) welding] requires consumable electrodes and inert gases and is not used frequently in the automotive industry.

Electron beam (E-B) welding, particularly ambient welding, is beginning to find application in the automotive industry. It is being used by General Motors to weld the frames for several car models and to weld collapsible steering columns. The nonvacuum unit is being planned for use in high volume production edge welding of the General Motors catalytic converter container for their 1975 model year emission control system. For this reason, E-B welders are emphasized in the subsequent discussion and the specific quotation from Hamilton-Standard to General Motors for six welders is detailed.

An ambient, or nonvacuum, E-B welder designed for production line welding is shown in Figure 8-7. A schematic illustrating three types of E-B welders is given in Figure 8-8.

8.3.1 Normal Production Schedules for Welders

Normal production schedules for resistance and E-B welders are shown in Figure 8-9. Resistance welders have an overall lead time of ten months for a standard welder and greater than ten months for a special welder, depending on the complexity involved. E-B welders for new applications can require up to 24 months development time with 18 months being considered more typical. This time is necessary to negotiate and establish welder design parameters by experimentation with the actual materials, thicknesses and welding rates.

The overall lead time from receipt of order to vehicle production for one E-B welder is in accordance with the following table.

E-B Welder Lead Times

A standard (needing minimum design effort) welder generally requires 11 to 12 months.

A standard (needing minimum design effort) welder/tooling package generally requires 12 to 14 months.

A special (needing maximum design effort) welder/tooling package generally requires 14 to 18 months.

8.3.2 Major Impact Factors for Welders

As can be inferred from the lead times tabulated above, the product design or welder complexity impacts the lead time in the amount shown.

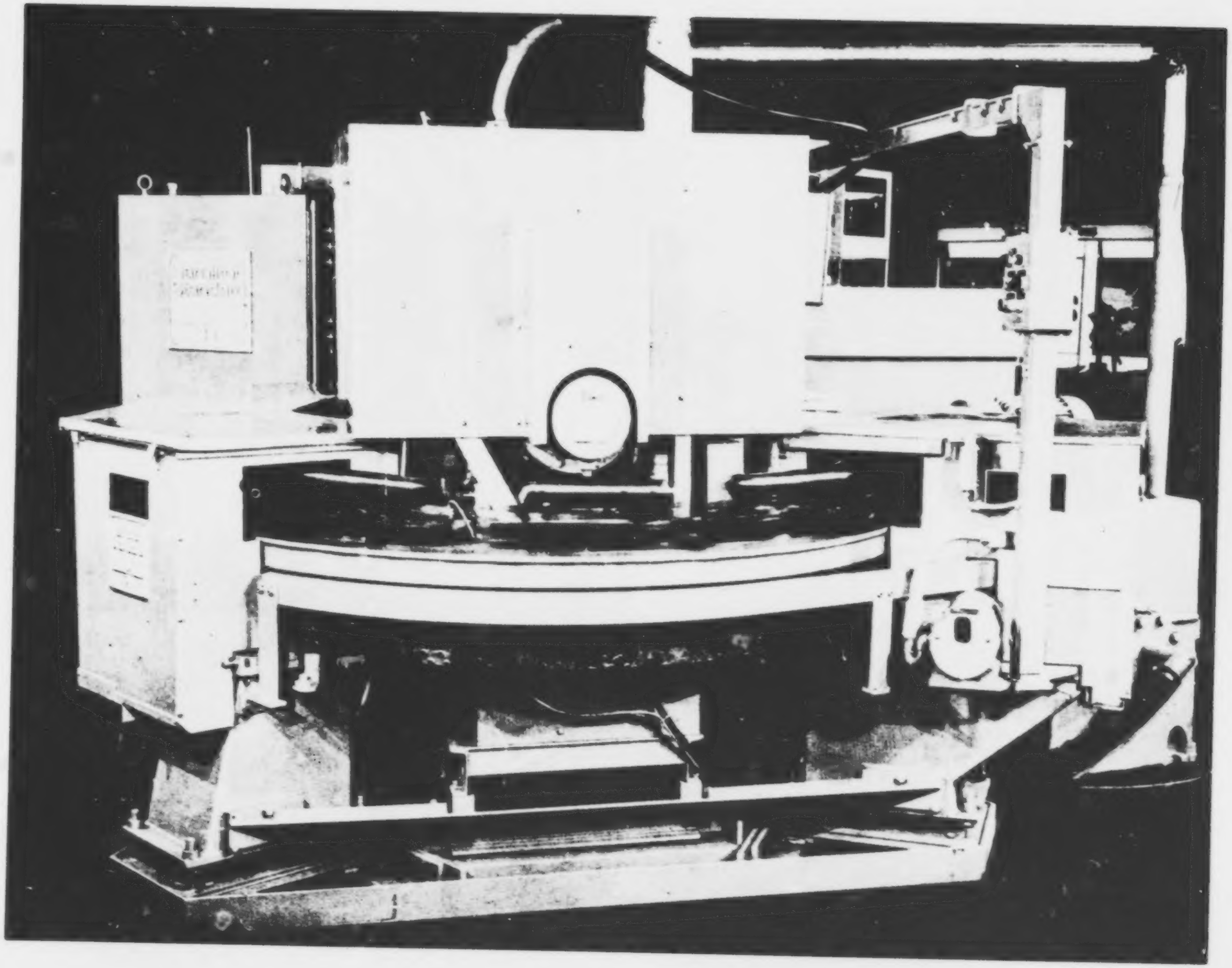


Figure 8-7. Nonvacuum Machine for Electron Beam Welding

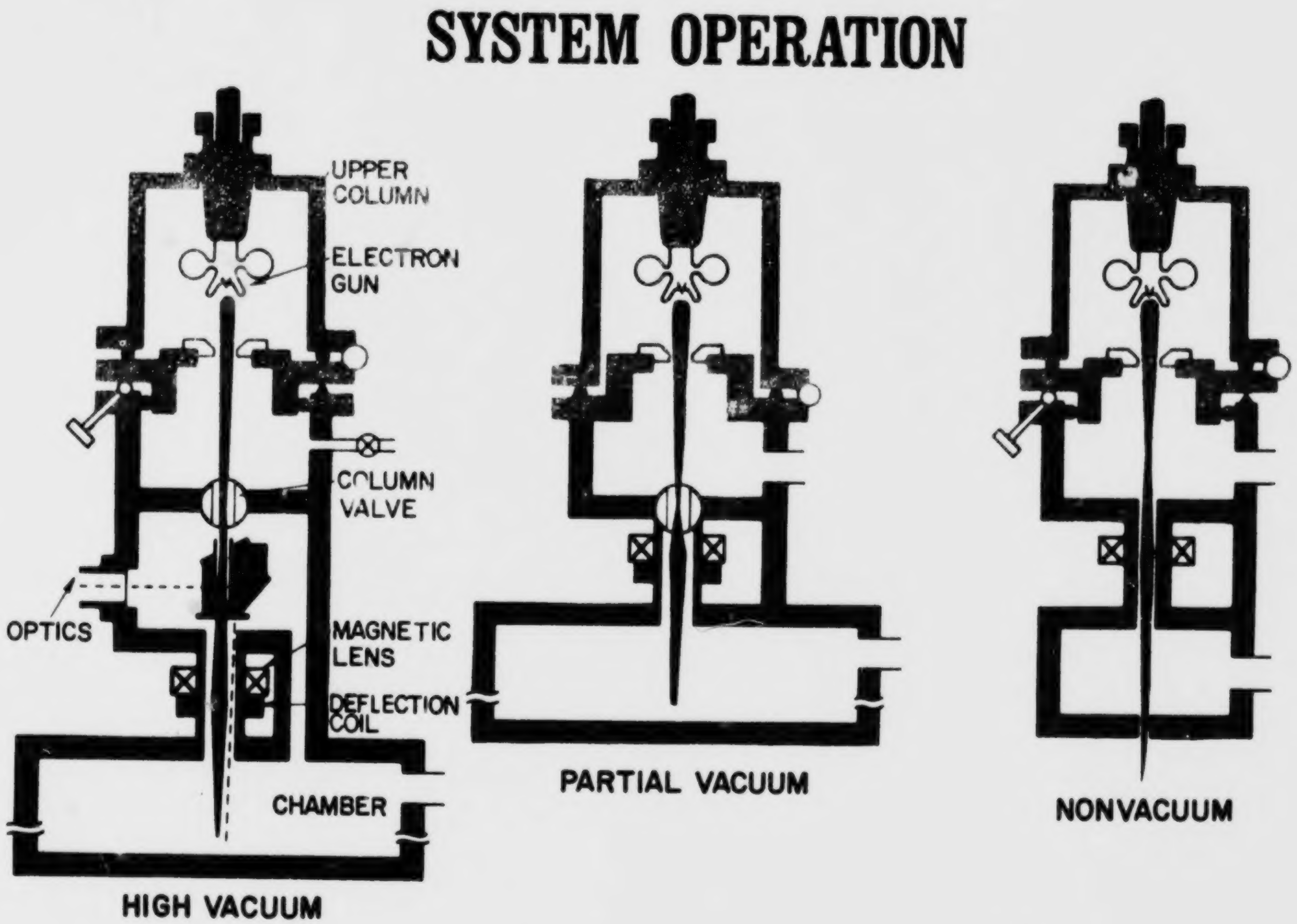

SYSTEM OPERATION
UPPER COLUMN
ELECTRON GUN
COLUMN VALVE
OPTICS
MAGNETIC LENS
DEFLECTION COIL
CHAMBER
HIGH VACUUM
PARTIAL VACUUM
NONVACUUM

Figure 8-8. Electron Beam Welders

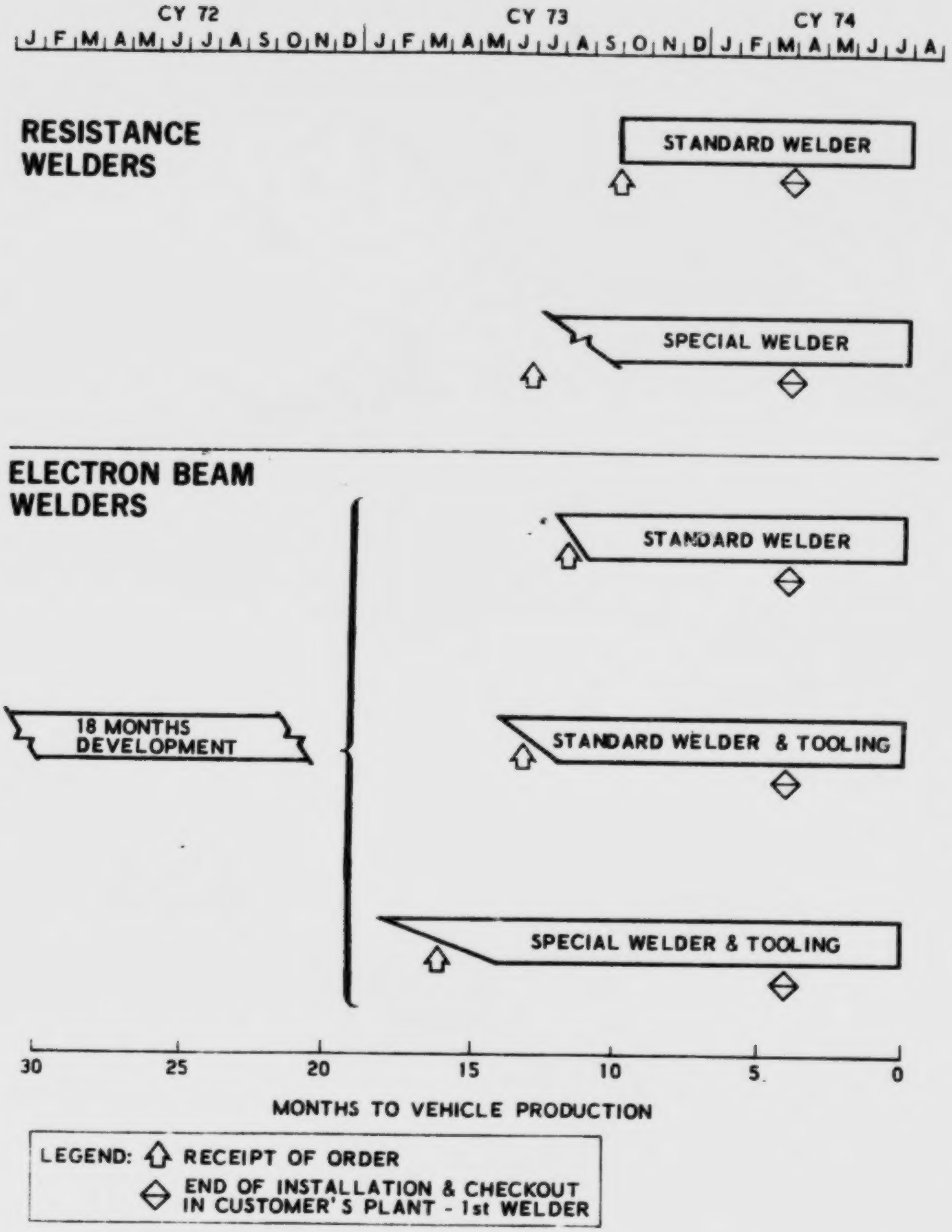


Figure 8-9. Production Line Welders Overall Lead Time

Another major impact factor for the E-B welders is the quantity of welders involved. As will be further elaborated upon, the overall lead time for six welders for General Motors adds 7-1/2 months to the schedule for one welder.

8.3.3 Major Elements in Welder Schedule

The major elements in an E-B welder schedule are listed as follows:

a. E-B Weld Column Assembly (Total lead time, design/manufacture, 14 to 16 weeks):
   1. Upper Column Assembly (individual lead time, casing/machining, 12 to 14 weeks)
   2. Cable/Insulator Assembly (individual lead time, 4 to 6 weeks)
   3. Gun Assembly (individual lead time, 3 to 4 weeks)
   4. Lower Column Assembly (individual lead time, casting/machining, 12 to 14 weeks)
   5. Lens (Alignment/Focusing) Assemblies (individual lead time, 8 to 10 weeks)

b. Vacuum System Assembly (Total lead time, design/manufacture, 10 to 12 weeks)
   1. Vacuum Ducting (flex/rigid) Assemblies (individual lead time, 3 to 4 weeks)
   2. Pump Assemblies (individual lead time, 4 to 6 weeks)
   3. Vacuum Valves (8 to 10 weeks)

c. Operating System Assemblies (Total lead time, design/manufacture, 22 to 24 weeks):
   1. Power Supply Assembly (individual lead time, 18 to 22 weeks)
   2. Motor Generator Set Assembly (individual lead time, 18 to 22 weeks)

d. Control System Assembly (Total lead time, design/manufacture, 16 to 18 weeks):
   1. Control Cabinet (individual lead time, 6 to 8 weeks)
   2. Control Modules (individual lead time, 12 to 14 weeks)

3. Control (relays, starters, meters, etc.) Components (individual lead time, 6 to 8 weeks)

e. Accessories (Total lead time, design/manufacture, 30 to 34 weeks):

1. Tooling (individual lead time, 30 to 34 weeks)
2. Lead Shielding Room/Box (individual lead time, 16 to 18 weeks)

f. Final Assembly/Test, Shipment and Installation (Total lead time, 10 to 16 weeks)

1. Machine Finished - Assembly/Test, 6 to 10 weeks
2. Teardown (painting and rigging for shipment), 12 to 16 days
3. Field Installation, 2 to 4 weeks

8.3.4 Lead Time for E-B Welders for General Motors Catalyst Container

For the specific welder for the General Motors pellet catalyst container, a prototype welder capable of 20 parts per hour has been built and shipped to the AC Sparkplug Division of General Motors Corporation. The prototype was developed as a crash program with concurrent development and manufacture taking place. The development time began 14 months prior to receipt of order for the prototype. The prototype lacks the handling equipment and numerical controls that will be incorporated into the production welder. The timing of the prototype is shown at the top of Figure 8-10.

The latest planning for the six production welders, each with a capability of welding 156 containers per hour, is also shown on Figure 8-10. Design layouts were expected to be completed around the first of November 1972 at which time the order was expected and detailed engineering was to begin. Concurrently, the long lead purchase parts will be ordered. The impact of quantity procurement is again noted where the order for six welders must be placed 7-1/2 months earlier than an order for one welder.

This schedule has been compressed by two months when compared to a normal schedule which had been quoted earlier. The welder deliveries have been moved forward in time and the installation and checkout period at AC Sparkplug has been compressed.

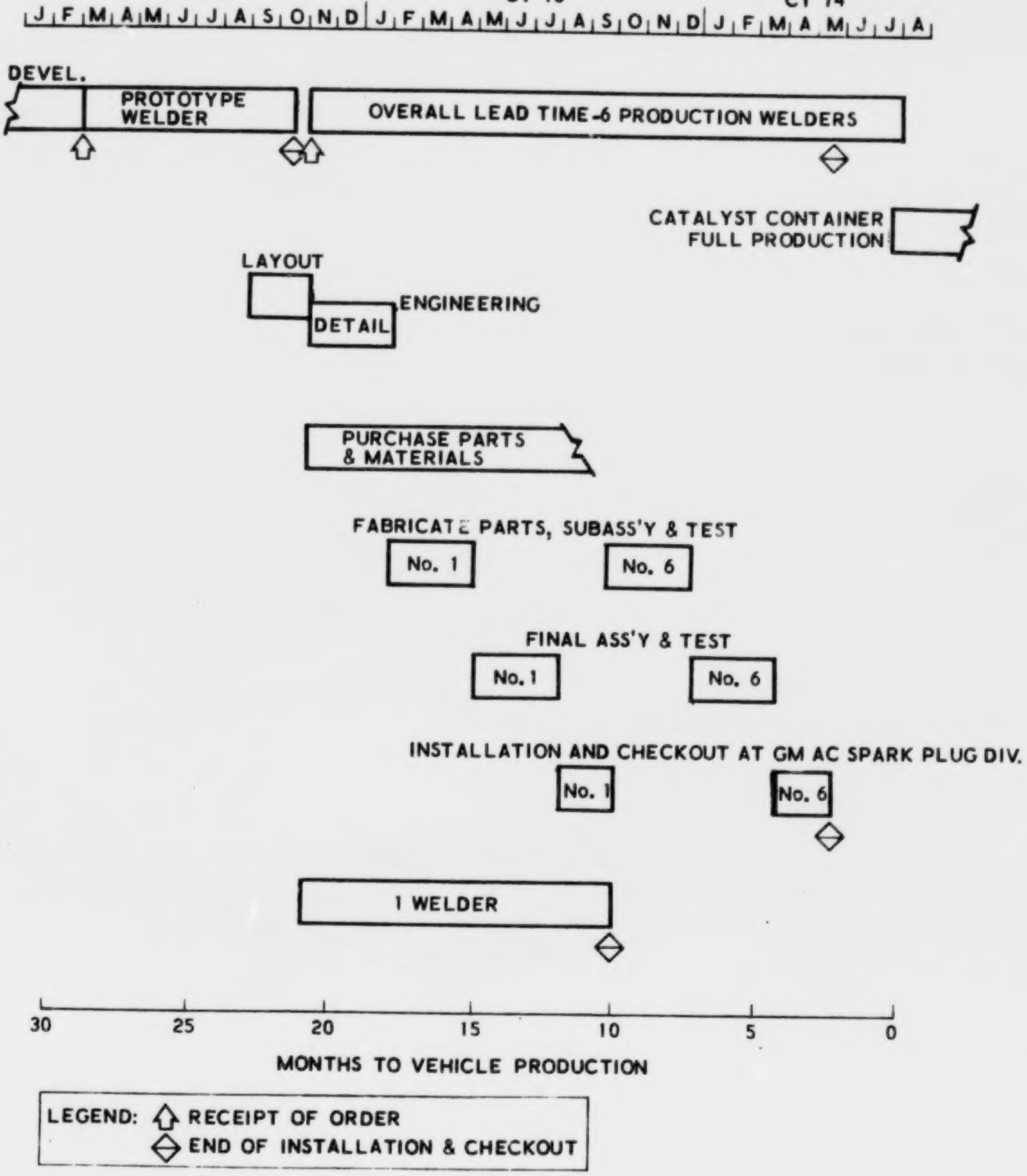


Figure 8-10. Electron Beam Welder Compressed Lead Time Order for Six Welders for General Motors Catalyst Container

On this basis the overall lead time for the six production welders from receipt of order to vehicle production is 21 months. Shipment of the welded production catalyst containers from the AC Sparkplug Division to the various General Motors assembly plants must begin in April or May 1974 to meet the 1975 model year schedules.

SECTION 9

LEAD TIME SCHEDULES FOR NONAUTOMOTIVE INDUSTRY MANUFACTURERS

9.1 INTRODUCTION

To provide additional insight into automotive industry lead time requirements, production schedules for model changes and/or new model designs were obtained from three nonautomotive industry manufacturers. Two of these companies, the Westinghouse Corporation and the General Electric Company, manufacture major household appliances. The third company, the Outboard Marine Corporation, manufactures Evinrude and Johnson outboard engines and other small engines for lawn mowers, chain saws, golf carts, and snowmobiles.

In addition to the schedule data, supplemental information relating to the special requirements of these manufacturers was also obtained. This material was considered essential to understand the major impact factors on nonautomotive industry production lead time requirements and to determine the relevancy of these schedules as compared to those of the automotive industry.

9.2 THE WESTINGHOUSE CORPORATION - COLUMBUS, OHIO

9.2.1 Background

The Westinghouse facility in Columbus, Ohio manufactures major household appliances. Its product line includes refrigerators, freezers, dishwashers, water coolers, and a small number of room air conditioners. These appliances are produced in large numbers and in some lines, such as refrigerators, the production rate is comparable to that which characterizes the automotive industry.

While the mechanical parts of these appliances are relatively simple in comparison to those of an automobile, they have exacting requirements, particularly those related to the durability of the product. A life of 15 or more years is expected from some of the appliances, notably refrigerators. As a result, considerable development testing of a new mechanical design is performed prior to its commitment for production. Since it is difficult to accelerate testing in a manner that would properly simulate its operation during the expected life of the product, this testing is carried over into the production phase.

Cost is of prime importance in the manufacture of these products. This is exemplified by the fact that appliance costs in the past 10 years have remained relatively constant and in some cases have even declined, while the price of other products has substantially increased. The number and complexity of the changes that are made to these products are definitely influenced by cost. In fact, most of the appliance changes are made on the basis of reduced-cost benefits.

While new appliance models are introduced annually, the changes incorporated are primarily style changes, such as trim and color options, and include only small improvements in the basic design. Taking the refrigerator as an example, the only major mechanical change made in the past 10 years is the design of a new compressor. Other major design-type changes that have been made in the recent past are the relocation of the condenser, which was accomplished in 1963, and the relocation of the evaporator in 1968. Except for the introduction of a foam insulation material in the more expensive models, no other significant changes have been made in the Westinghouse refrigerator line.

The manufacture and assembly of these appliances is mostly accomplished within the Westinghouse facility and only a very limited number of fabricated parts are procured outside. It is also the practice of this industry to implement changes on a single model only, similar to that which is done in the automotive industry.

Once the model changeover has been accomplished, a single line can run a variety of models in batches, with changeover from one model to another model accomplished in a matter of hours. The batches run from a low of 500 to a high of 10, 000 at a rate of 300 to 1500 per day as the upper limit. A single shift operation for assembly is the usual practice. However, it is possible to run two shifts where required. The capacity limitations are in the feeder areas where the components, such as compressors, are made.

9.2.2 Lead Time Schedules

As mentioned above, modifications made for annual model changes are relatively simple and primarily involve styling changes. The lead time schedule for a typical model change for a refrigerator is shown in Figure 9-1. The total elapsed time for this change was 26 weeks, which includes a period of 1 to 2 weeks for market reviews and management decisions that are not basically a part of production lead time. The critical lead time element in this schedule is the 19 weeks for the tooling required to pierce the outer door.

The production lead time schedule for a major refrigerator change is shown in Figure 9-2. This change called for the relocation of the evaporator from the inside back wall of the refrigerator compartment to the divider between the refrigerator and freezer compartments. In addition, a foamed-in-place-type insulation was included with this change but applied only to the more expensive models. The key elements of this schedule are discussed below.

Phase I. This Phase primarily involves a market survey to determine customer preferences for volume and styling requirements, and an investigation of competitive designs. Since capital commitments have not been made, this Phase is not applicable to production lead time requirements.

Phase II. Two to three months are required to fabricate two units of each model ("soft tooling" is used in the manufacture of these prototypes). Four to five months are required for testing of the prototypes. When this testing has sufficiently progressed, it is the

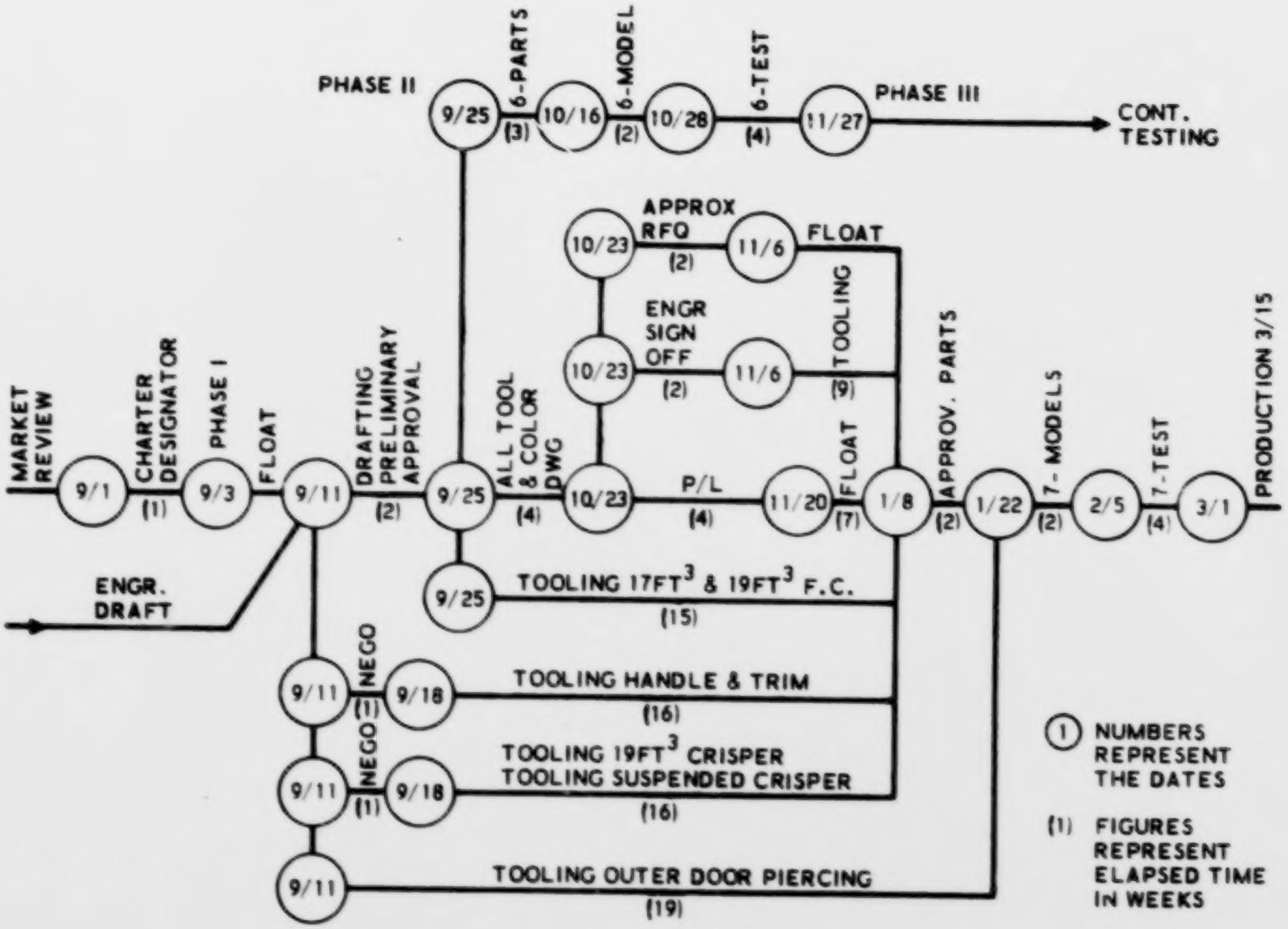

PHASE II
9/25
6-PARTS
(3)
10/16
6-MODEL
(2)
10/28
6-TEST
(4)
11/27
PHASE III
CONT. TESTING
MARKET REVIEW
9/1
CHARTER DESIGNATOR
(1)
9/3
PHASE I
FLOAT
9/11
DRAFTING PRELIMINARY APPROVAL
(2)
9/25
ALL TOOL & COLOR DWG
(4)
10/23
P/L
(4)
11/20
FLOAT
(7)
1/8
APPROV. PARTS
(2)
1/22
7- MODELS
(2)
2/5
7-TEST
(4)
3/1
PRODUCTION 3/15
ENGR. DRAFT
10/23
APPROX RFQ
(2)
11/6
FLOAT
10/23
ENGR SIGN OFF
(2)
11/6
TOOLING
(9)
9/25
TOOLING 17FT³ & 19FT³ F.C.
(15)
9/11
NEGO
(1)
9/18
TOOLING HANDLE & TRIM
(16)
9/11
NEGO
(1)
9/18
TOOLING 19FT³ CRISPER
TOOLING SUSPENDED CRISPER
(16)
9/11
TOOLING OUTER DOOR PIERCING
(19)
(1) NUMBERS REPRESENT THE DATES
(1) FIGURES REPRESENT ELAPSED TIME IN WEEKS

Figure 9-1. Westinghouse Critical Path Network

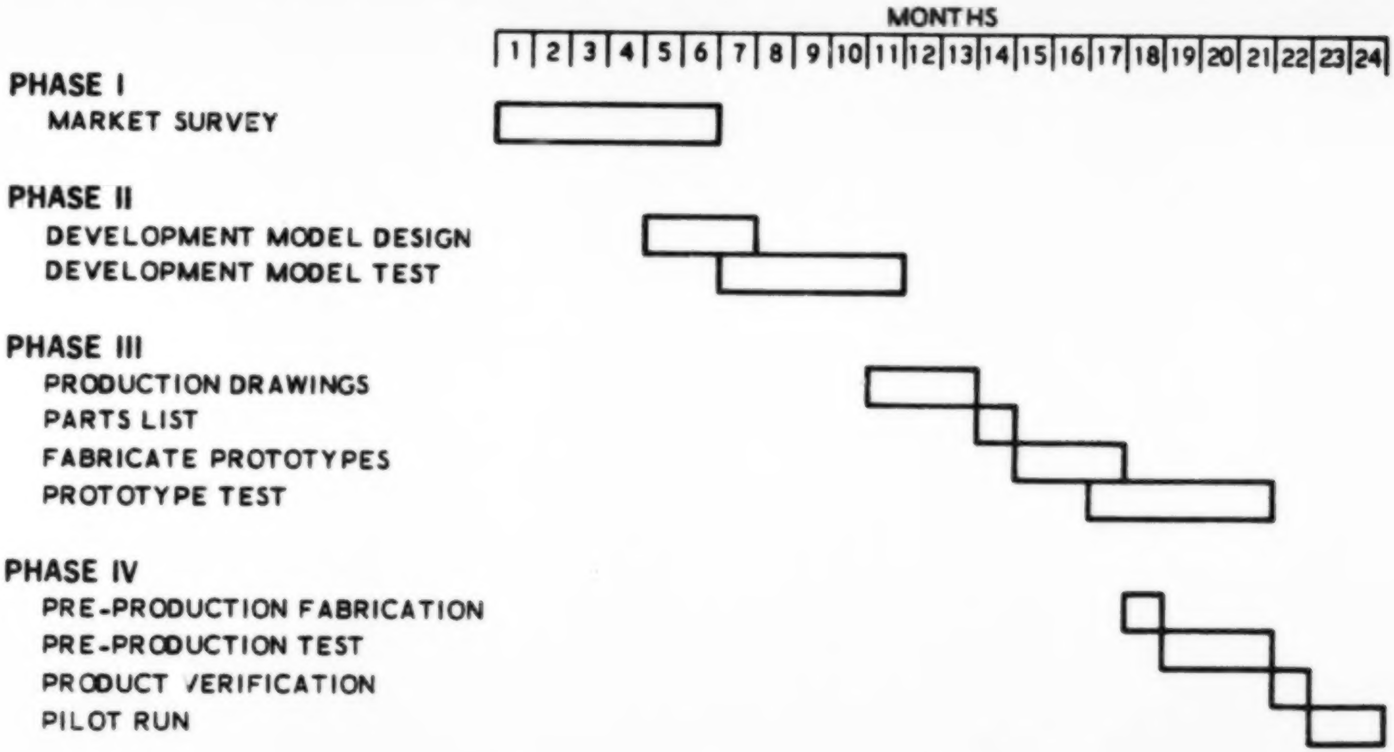


Figure 9-2. Westinghouse Refrigerator Evaporator Relocation

practice to release long lead time tooling requirements. The actual production lead time, therefore, can start as early as the fourth month of Phase II if the tests of a particular change have progressed satisfactorily.

Phase III. Three months are required to detail production drawings and one month is required to prepare a parts list. A 2 to 3 month period is then involved in the fabrication of prototype models built from production drawings. Prototype testing takes about 5 months.

Phase IV. Four months are required to check out tooling and to fabricate parts for the preproduction test of up to seven models. An additional 2 or 3 months are required to progress from a low rate pilot run to full rate production.

Generally, anything that requires over 4 months to procure is considered a long lead time item by the industry. In this particular case, the exceptional long lead time of 14 months for the procurement of the foaming equipment made it the critical element in the schedule.

The production lead time requirement for a change of this type is normally 14 to 18 months, depending upon the particular circumstance. However, the lead time requirement for a completely new appliance design was estimated by Westinghouse to be approximately 30 months. This was based on their recent experience with the development of a dishwasher of completely new design.

9.3 THE GENERAL ELECTRIC COMPANY - LOUISVILLE, KENTUCKY

9.3.1 Background

The product line manufactured at the General Electric facility in Louisville, Kentucky includes refrigerators, dishwashers, garbage disposals, ranges, air conditioners, and laundry machines. Like Westinghouse, General Electric is also a major producer of household appliances. Its average production rate is approximately 60 units per hour. Some of these appliances (home laundry equipment) are produced at rates as high as 120 per hour.

The technology effort at General Electric focuses on reliability and, in general, changes are made which do not push the state of the art. New concepts are usually introduced on a single model and then are spread across an entire line. From the time a change is introduced on one model until it is introduced on all models, a period of 3 years may have elapsed.

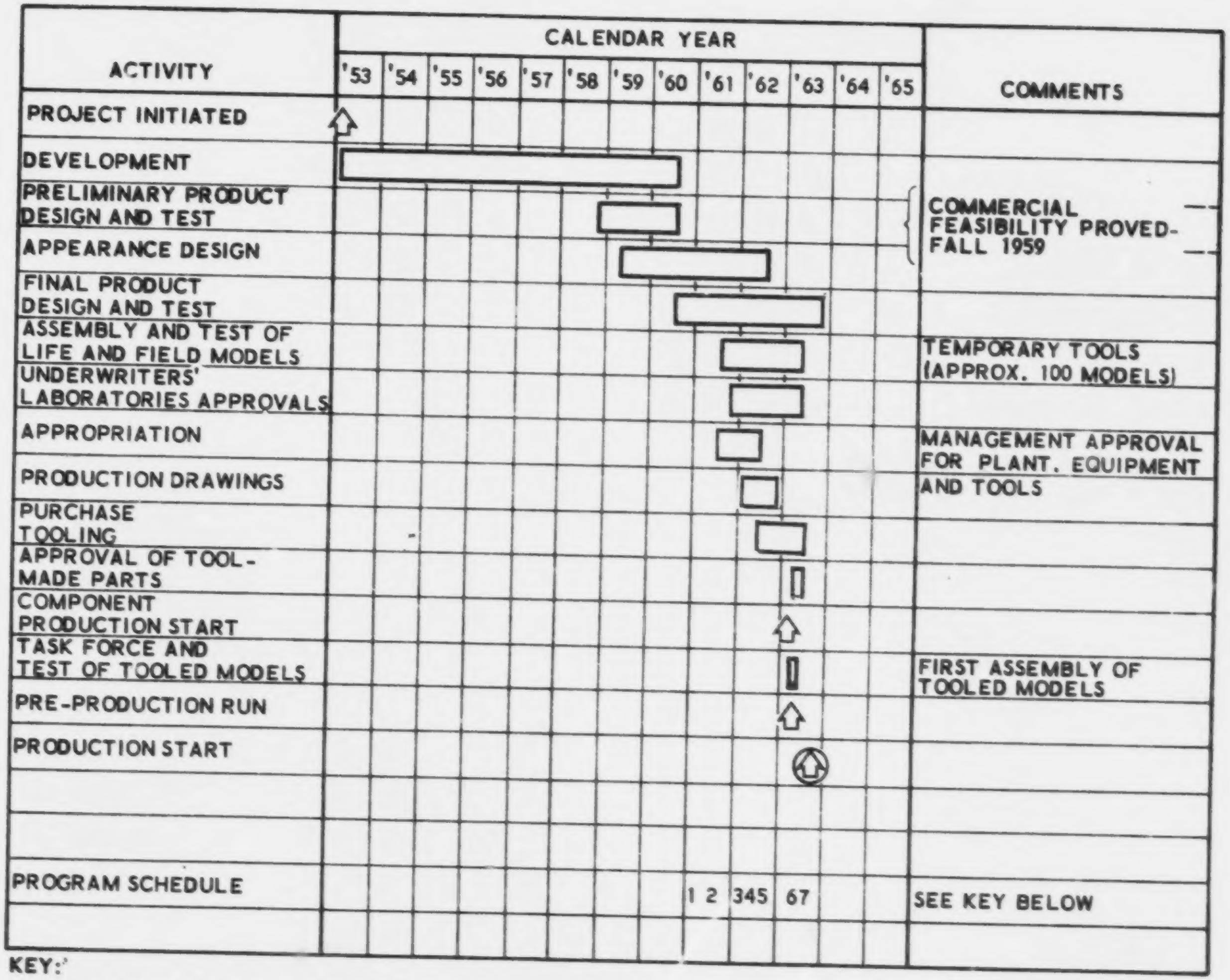
The implication of cost for home appliances has been already covered in the Westinghouse discussion. It is of interest to note, however, that the element of cost is much less significant when a change is accompanied by an attractive convenience. For example, the self-cleaning oven which General Electric put on the market a few years ago represented a 50% increase in cost over the basic appliance, yet it has received very good customer acceptance.

Most of the components for General Electric appliances are manufactured in-house. This includes all of the sheet metal parts as well as several castings. Transfer machinery (manufactured by the Cross Company) is used in some operations, for example in the manufacture of transmissions for its automatic dishwashers.

9.3.2 Lead Time Schedule

The General Electric production lead time schedule for a self cleaning oven is presented in Figure 9-3. This oven is basically a new product which required many years of research and development to bring it to the production stage. A great deal of data were provided to amplify the information presented in this schedule. However, most of the data were directed toward emphasizing those details associated with the development phase and only limited data were provided which would clarify the production part of the schedule.

With regard to the development schedule, the concept was first delineated in February 1953. First production was not achieved until August 1963, more than 10 years later. Manufacturing engineering became involved in the program in the fall of 1960. Management approval and signoff for production go-ahead was given in the fall of 1961. At this point, the



KEY:

1- PRODUCT PLANNING REVIEW, 2- ENGINEERING REVIEW, 3-DESIGN REVIEW,
4- APPROPRIATION APPROVED, 5- LIMITING DRAWINGS RELEASED,
6- TASK FORCE, 7- PRODUCTION START

Figure 9-3. General Electric P-7 Self-cleaning Over Program

product still lacked a satisfactory high temperature control device and a satisfactory oven rack finish. First drawing release occurred early in 1962; the last release occurred in the fall of 1962.

The elements of this schedule that apply to production lead time requirements start with the appropriation approvals that were initiated in the third quarter of 1961. Production drawings were initiated prior to final appropriation approval to provide drawing releases for the procurement of tooling that had a long lead time requirement (9 months).

Sample production parts were made from production tooling 3 to 4 months prior to a pilot production run to verify the production tooling. About 3 months in advance of the production target date, a pilot run at full production rate was made to check out the assembly operation. One hundred to one thousand units may be produced in this pilot run, depending on the particular appliance.

This schedule, which shows an elapsed period of 24 months from appropriation commitment to the start of production, supports the General Electric position that in the appliance field a minimum of 2 years of production lead time is required for a change of major complexity.

9.4 THE OUTBOARD MARINE CORPORATION - MILWAUKEE, WISCONSIN

9.4.1 Background

Outboard Marine is a major producer of small horsepower engines for applications such as lawn mowers, golf carts, and chain saws. Its primary production at the Milwaukee facility, however, is the manufacture of the two-cycle Johnson and Evinrude outboard engines. Historically, Johnson and Evinrude were separate companies which merged in the 1930s. These two engines are now identical except for external trim. They are produced on a common assembly line in sizes ranging from 2 to 135 horsepower. The production rate for these outboard engines is approximately 100,000 units per year.

In addition to outboard engines, a 35-horsepower Wankel engine is being manufactured at the Milwaukee facility in limited production quantities. This engine is planned for incorporation into a snowmobile produced by the Canadian facility of the company and is scheduled to be marketed late this year.

The mechanical design of these engines is, of course, considerably more complex than the design of household appliances. The functional parts, which include the basic engine, gear reduction, drive train, and exhaust and cooling systems, are comparable in mechanical complexity to their automotive counterparts.

The requirements for these engines emphasize compactness of design with resulting low weight-to-horsepower ratio. The durability requirements for the outboard engines are based on meeting a 5-year life expectancy. This period of time typically involves approximately 500 hours of service operation accumulated at the rate of 100 hours per year. Since the operating condition for this engine is almost exclusively at wide open throttle, the design of the engine must be precisely controlled in order to achieve the durability requirement.

9.4.2 Lead Time Schedules

A schedule for a model year change which included a new mechanical starter system is shown in Figure 9-4. The total production lead time to accomplish this change was 30 months. The critical element in this schedule was the lead time for procurement and try-out of the die-cast tooling which required approximately 54 weeks. The terms "explode pilot run" and "explode model" refer to production control milestones at which time the production rates for parts are computed.

Since Outboard Marine manufactures most of its engine parts (except for electrical components and miscellaneous nuts and bolts), tooling procurement is almost always the critical element in its production schedules. The lead time required for tooling procurement ranges from 42 to 54 weeks. An additional 4 to 8 weeks are required to prove out the dies.

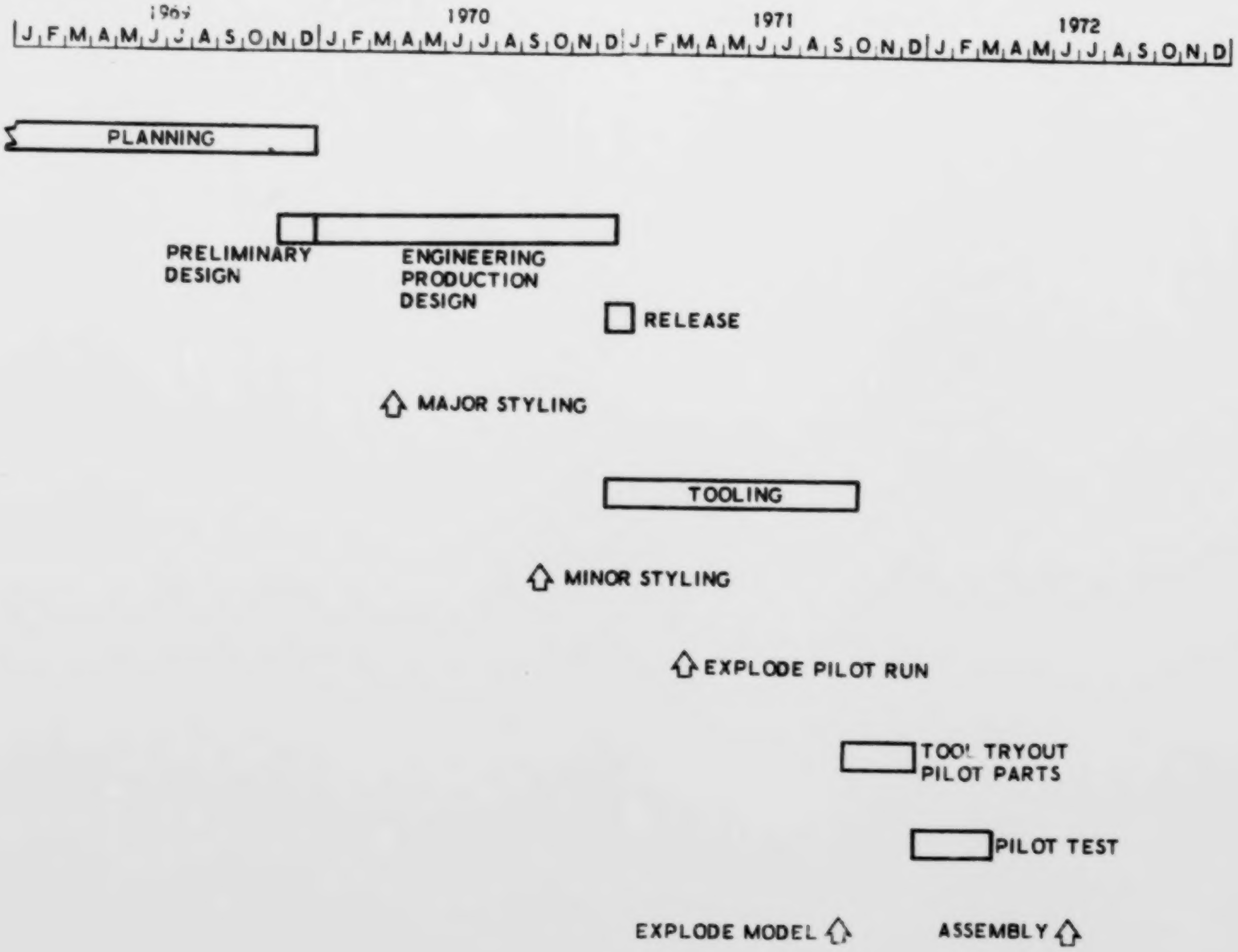


Figure 9-4. Outboard Marine Lead Time Schedule for 1973 Model Year Engine

Another production lead time schedule is shown in Figure 9-5. This is a schedule for the 35-horsepower Wankel engine being introduced into the 1973 model snowmobile. It should be noted that this schedule covers only the period from engineering release to the time at which assembly begins. Not shown on this schedule is a period of 2 1/2 years which preceded the engineering release. Also, no new facilities were required for the low production rates planned.

This extended pre-engineering release period is not typical of the Outboard Marine schedules. The decision to commit the design to production was made before the development program was complete and the requirement for design changes which subsequently developed was the cause of this extension. In addition, the Begin Assembly date of April 1972 shown on this schedule has since slipped approximately 4 months. Production is now expected to begin in December 1972. The production lead time shown by this schedule, therefore, should be viewed with these comments in mind.

Although the production commitment to the Wankel engine included a recognized risk due to its development status, it was not a "crash" program. It was the opinion of Outboard Marine that "crash" programs do not significantly improve production lead time. It was estimated that doubling the cost to reduce lead time might result in only a 10% compression.

9.5 AUTOMOTIVE VERSUS NONAUTOMOTIVE LEAD TIME COMPARISON

From the information obtained from Westinghouse and General Electric, it is evident that significant product differences between the appliance and automotive industries will not permit a direct comparison of production lead time requirements. Elements common to the lead time schedules of both industries, however, can be compared on an indirect basis. By accounting for the differences in product complexity, design requirements, and manufacturing processes the consistency of requirements between the two industries can be examined.

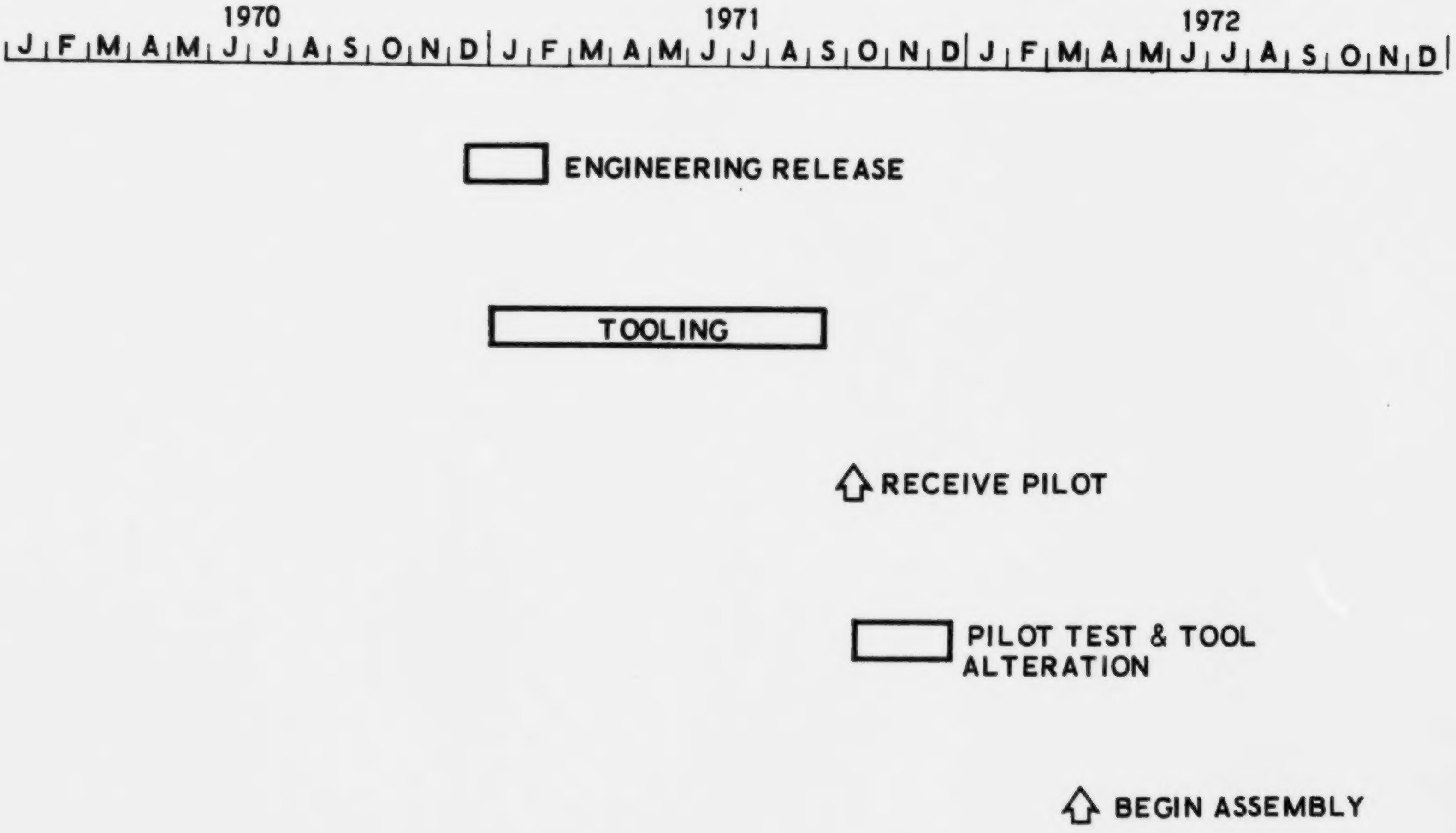


Figure 9-5. Outboard Marine Lead Time Schedule for 1973 Rotary Combustion 35-Horsepower Snowmobile Engine (Wankel)

Because of the simplicity of appliance design, product engineering for even a major change to an appliance should be significantly less than for an automobile model year change. This difference in product complexity is reflected to the expected degree by the 13 weeks required for the release of production drawings for the refrigerator change shown in the Westinghouse schedule (the comparable drawing release period for the automotive industry is 8 to 14 months). However, the 43 weeks required for the release of production drawings shown in the General Electric schedule for the self-cleaning oven does not reflect the same marked reduction.

Household appliances are characterized by sheet metal and bracketry which is simply formed with few, if any, contours. Therefore, the tooling required to form the sheet metal involves dies which are considerably less complex than those required for the contoured lines of an automobile. Accordingly, it would be expected that the lead time for the procurement and checkout of tooling for the appliance industry should be considerably less than for the automotive industry. The expected difference in elapsed time requirements is reflected by the 16 to 19 weeks required for tooling for the refrigerator change by Westinghouse compared to the 12 to 15 months for the automotive industry. Again, the General Electric requirement of 43 weeks to procure tooling for the self-cleaning oven does not reflect the same degree of lead time reduction.

Because of the similarity in the type of product, the lead time requirements for the production of outboard motors may be more relevant to those requirements for the automotive industry. Therefore, a comparison can be made of elements which are common to the production schedules of both industries. In addition, an indirect comparison can be made of the production lead time requirements for a model year change by accounting for differences in product complexity and production rates.

A common element in the outboard engine and automotive industry schedules is the production time required for the procurement and checkout of tooling. In this case the 54 weeks required by the outboard engine industry compares favorably with the 12 to 15 months required by the automotive industry.

The typical production lead time required for a model year change is 30 months for outboard engines and about 25 to 28 months for automobiles. While the tooling lead time requirements are similar overall, differences in product complexity and production rates might be expected to result in a production lead time for outboard engines that is less than that for automobiles. The comparison, however, did not reflect this effect.

The production schedule for the Wankel engine that is produced by Outboard Marine is a special case and is not typical of the lead time requirements for the manufacture of outboard engines. It must be recognized that a production commitment for this engine was made at a time when the development was somewhat incomplete. While this is relevant to the present situation of the automotive emission control devices, the very limited production planned for the Wankel engine does not allow for a meaningful comparison.

SECTION 10

LEAD TIME SCHEDULES FOR A GOVERNMENT AUTOMOTIVE PROCUREMENT AGENCY

The U. S. Army Tank Automotive Command (ATAC) is a government agency responsible for the design and procurement of specific classes of vehicles for all military services. The vehicles over which they have cognizance are (a) those built to military design, (b) commercial vehicles modified to military requirements, and (c) nonmodified commercial vehicles over 10,000 pounds gross weight. Commercial vehicles for military and other use which are less than 10,000 pounds gross weight are procured by the General Services Administration, Washington, D. C.

10.1 NORMAL PRODUCTION SCHEDULES FOR GOVERNMENT VEHICLES

10.1.1 Case History I - M151 Jeep

An example of the lead time schedules involved is the history of the M151 vehicle. The M151 is a 1/4 ton general purpose (G. P. or "jeep") utility vehicle which represents a product-improved M38 World War II jeep. The M151 was developed in conjunction with Ford on a development contract. After the development, ATAC had a complete set of drawings which were used for bid purposes for production orders in 1958. Probably by virtue of its development experience, Ford won the production order. The time from production contract award to delivery of the first vehicle was stated by ATAC as being approximately 13 months. The production rate was less than 2,000 per month. Ford acted basically as an assembler, having procured about 90% of the parts.

It is ATAC practice to subject the initial production vehicles to Initial Production Testing (IPT) for performance verification. Normal practice is to warehouse the first run of production vehicles in Army depots until completion of IPT to simplify any retrofit that the IPT results might require. For this reason a slow buildup to the full production rate is scheduled.

10.1.2 Case History II - M151A2 Jeep

Modifications were made to the M151 Jeep, and production orders were placed with various producers including American General Corporation (formerly Reo-White). The current order is for the vehicle designated M151A2. Prior to this time Ford had the last production order. The government owned the tooling ($3 million) and planned to furnish it to the successful bidder.

Bids were received for 34,000 vehicles to be produced over a 3-year program. ATAC normally commits to a production order only over its first funding year. It retains the option to incrementally pick up production bid orders year-by-year over subsequent funding years.

A two-step bid process is normally employed. First, Request for Proposals (RFP's) are released for technical proposals. The responses are evaluated, schedules are negotiated, and Request for Quotations (RFQ's) are sent out to qualified bidders. The contract is awarded subsequently. The actual and planned events scheduled for the M151A2 are noted below:

August 10, 1970	RFP for technical proposals released. The desired delivery schedule is in the RFP. An optimum schedule is established considering vehicle inventory objectives, minimum vehicle cost, the 5 year planning schedule and funds availability. In this instance two delivery schedules were prepared. One was for Ford, which was in production at this time, and one for all other qualified bidders. The agency desires a slow production buildup to minimize storing vehicles during IPT.

September 26, 1970	Technical Proposals received and evaluated. Schedules negotiated with qualified bidders. Production contracts are not usually placed with a producer who requires new facilities or major equipment.
December 10, 1970	RFQ for cost proposals released.
January 12, 1971	Cost proposals received.
February 16, 1971	$117 million contract for 34,000 vehicles awarded to American General. Tooling shipped to American General.
January, 1972	Two vehicles received. Ship vehicles to Army Proving Ground for IPT.
Subsequently	Production buildup. American General behind in meeting proposal delivery schedule. New delivery schedule negotiated. Army stores vehicles until IPT completed.
February 14, 1972	EPA waiver received exempting first 19,000 vehicles from emission standards.
April, 1972	Begin IPT.
May 15, 1972	Begin certification test of second engine type.
September 15, 1972	Complete IPT.
October 15, 1972	Complete second engine type certification tests.
April 15, 1973	Agency may pick up option for second year vehicle order.

For this case of a 2,000 per month ultimate production rate, with the equipment and most of the tooling on hand and the manufacturer having experience with the design, the production lead time was 11 months to delivery of first vehicle. Figure 10-1 depicts the lead times. An additional 7 months was required to approach the 2,000 per month production rate.

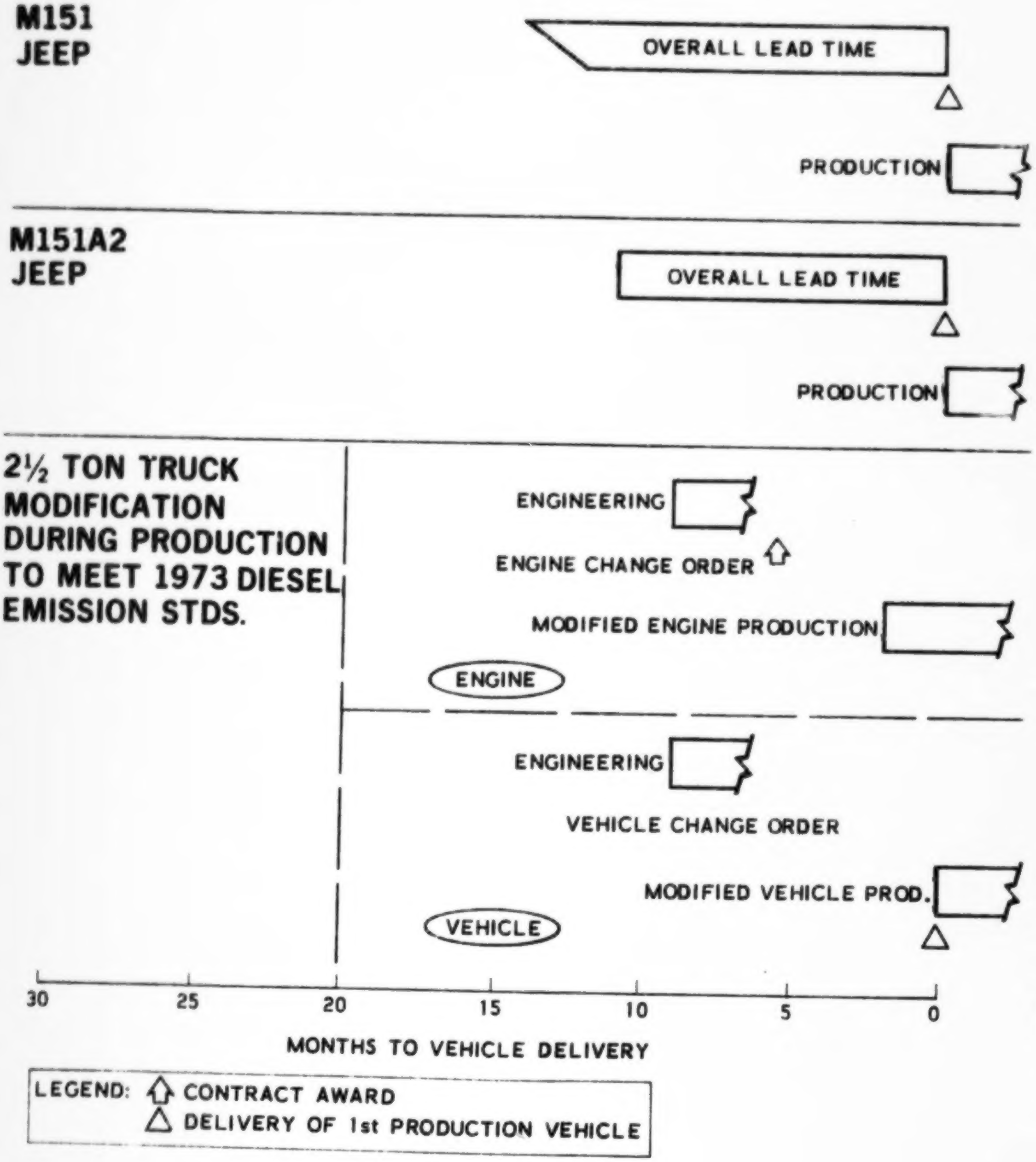


Figure 10-1. Military Vehicle Procurement Lead Time

10.1.3 Case History III - 2 1/2 Ton Truck

Also shown in Figure 10-1 is the lead time involved in accomplishing a change during a production run of 2 1/2 ton trucks. Vehicle production was constant at about 800 per month. During October 1971, there were four contracts in effect that were involved in the change. American General had the production contract for assembly of the 2 1/2 ton truck and received the LD465 engine as government furnished equipment. Hercules, Inc. had the production contract for the engine. Another division of American General had an open end contract for development and engineering on the vehicle. Teledyne-Continental Motors had an open end development and engineering contract for the engine which was its own design. Work was done on the open end contracts only by special engineering directives from ATAC.

Delivery of subsequent year option vehicles was scheduled to begin July 1, 1972. Those vehicles required modification to meet 1973 diesel emission standards. The contract release for the option was made during October 1971. Apparently as an inducement to secure the contract option, American General promised to work with Hercules and guaranteed that the contract option vehicle would meet the emission standards. Also, in October, 1971, an engineering directive was released to Teledyne-Continental to modify the LD465 engine to meet the standards. An engineering directive was also released during October 1971 to the division of American General responsible for development for work on the vehicle modifications necessary to meet the standards. The engine modification was essentially the addition of a turbosupercharger creating the LDT465 engine. The vehicle modifications included elimination of the muffler, a larger rerouted exhaust tube, and a larger cab cutout for the larger exhaust tube. The timing of events subsequent to October 1971 were:

January 14, 1972	Engine change order released to Hercules.
January, 1972	Begin EPA certification tests.
April 6, 1972	Vehicle change order sent to American General.
May 1, 1972	EPA acceptance of engine.

May, 1972	Begin delivery of LDT465 production engines.
July 1, 1972	Begin delivery of 800 production vehicles per month which meet 1973 diesel engine emission standards.

Production lead time to accomplish the change is considered to begin with the release of the engine change order on January 14, 1972 and end at the delivery of production vehicles on July 1, 1972, or 5 1/2 months lead time. ATAC felt this to be a fast response time.

An example of a much longer lead time was the case cited for an engine transmission. Transmissions for special military designs that were formerly made, but are not now in production, would require an 18 month lead time. The pacing items are die castings, which would take 9 to 12 months.

10.2 MAJOR IMPACT FACTORS FOR GOVERNMENT VEHICLES

It is noted that the procurement lead times for government vehicles are considerably less than the new model production lead time requirements for commercial passenger automobiles (i. e., 11 to 14 months noted previously for a jeep vs. about 25 to 28 months for a new model year light-duty car). Several factors appear to contribute to the shorter lead time.

The major influencing factors are the pre-existing development and tooling status at the time of procurement decision,and the low production rate of government vehicles--one to two orders of magnitude less than passenger car rates. With the low rate, it apparently is not economical for a producer to make his own parts, so they become purchase items from manufacturers who have equipment and facilities available, thus eliminating the time to set up parts production lines. The producer acts primarily as an assembler with a low production rate assembly line which requires much less time to establish since a high degree of automation is not economically justified.

The other factors that contribute to the shorter lead time seem to be:

1. Tooling is available in some cases and furnished by the government to the producer.
2. The design may be known to the producer and he may have had production experience with it.
3. The government normally will not let a contract to a bidder who requires major equipment or facilities.
4. The government establishes a slow buildup to the full production rate.

SECTION 11

PROJECTED WORLD PRODUCTION AND USAGE OF NOBLE METALS*

11.1 INTRODUCTION

This section presents an assessment of the projected world production of noble metals and the demand for these metals resulting from the use of catalytic converters in the emission control systems currently projected for the 1975 and later model year vehicles.

The information included in the following sections was obtained primarily from three sources: the Bureau of Mines platinum-group metals reports, the EPA in-house study on platinum supply and demand, and discussions with representatives of a number of automobile and catalyst companies.

Section 11.2 presents a discussion of the principal noble metal producing countries and companies in the world. Section 11.3 discusses the projected noble metal demand of the automotive industry. The noble metal supply and demand balance between 1972 and 1983 is evaluated in Section 11.4, and the conclusions are presented in Section 11.5.

11.2 WORLD PRODUCTION OF NOBLE METALS*

11.2.1 General Information

The platinum group consists of platinum, palladium, iridium, osmium, rhodium, and ruthenium. The most important and most abundant elements are platinum and palladium. As discussed in Section 6 of this report, both platinum and palladium are being considered by the automobile and catalyst manufacturers for use in their proposed 1975/76 vehicle emission control systems.

---

*The term "noble metals," as used in this report, refers to the platinum group metals.

During the second quarter of 1972, the producer prices of platinum rose from $110 to $120 per troy ounce to $120 to $125 per troy ounce, and palladium rose from $36 to $38 per troy ounce to $38 to $41 per troy ounce (Ref. 11-1). In the same time period, the dealer prices per troy ounce increased to approximately $140 for platinum and $42 for palladium.

11.2.2 Noble Metals Production -- By Country

The annual noble metal production rates for 1969 through 1971 are listed in Table 11-1 (reproduced from Ref. 11-1). As indicated in this table, the Soviet Union is the world's largest producer of noble metals, followed by South Africa and Canada. The United States production amounts to less than 1% of the total world production.

11.2.2.1 South Africa

The Republic of South Africa is by far the most important noble metal producer in the free world. According to a recently conducted study by the Bureau of Mines (Ref. 11-2), South Africa's total noble metal production capacity for 1972 is estimated at 2.45 million troy ounces. However, because of unfavorable market conditions, production in 1972 will be limited to about 1.45 million troy ounces.

In South Africa's noble metal mining operations, the noble metals are the principal products, with nickel being a co-product and gold and silver being by-products. Approximately 0.12 ounce of noble metals is obtained from each ton of South African ore. As indicated in Table 11-2, the composition of the noble metals extracted from the South African ore is approximately 71% platinum, 25% palladium, and 4% other noble metal elements (Ref. 11-2). Additional information on the South African noble metal mining companies is presented in Section 11.2.4.

Table 11-1. World Production of Noble Metals (troy ounces)

Country \ Year	1969	1970	1971[1]
Soviet Union	2,100,000[2]	2,200,000[2]	2,300,000[2]
Republic of South Africa	964,000[2]	1,502,800[2]	1,252,800[2]
Canada	310,400	482,430	468,000
Colombia	27,800	26,360	25,610
United States	21,590	17,310	18,030
Philippines	--	1,230	2,700[2]
Finland	--	650[2]	600[2]
Ethiopia	340	270	220
TOTAL	3,424,130	4,231,050	4,067,960

(1)Preliminary
(2)Estimated

Table 11-2. Estimated Noble Metal Composition (percent)

Element	South Africa	Soviet Union	Canada	Colombia
Platinum	71.2	30.0	43.4	90
Palladium	25.1	60.0	42.9	N.A.
Iridium	0.8	2.0	2.2	N.A.
Rhodium	2.4	2.0	3.0	N.A.
Ruthenium	0.5	6.0	8.5	N.A.
Osmium	0.01	0	0	N.A.

11.2.2.2 Soviet Union

Little concrete information is currently available on the noble metal mining and refining operations in the Soviet Union. The latest Bureau of Mines estimates for 1971 indicate an annual Soviet production of 2.3 million troy ounces (Ref. 11-1). The composition of the Soviet production is 60% palladium, 30% platinum, and 10% other noble metals. In the Soviet Union, the noble metals are obtained almost entirely as by-products of the nickel and copper refining operations conducted in the Norilsk area of northwestern Siberia, the Kola Peninsula, and the Ural region. In 1971 the Soviet Union exported at least 75% of its total noble metal production. Approximately 700,000 ounces were sold to Japan and about 400,000 ounces to the United States. In addition, unknown quantities of Soviet noble metals reached western markets through a number of West European countries (Ref. 11-3).

The noble metal production in the Soviet Union is expected to increase by only 5% per year through 1975. Then production could increase substantially as a new nickel plant, currently under construction in the Norilsk area, becomes productive. Although the Soviet Union may be forced to further increase its noble metal sales in order to finance its imports of industrial equipment, future exports of noble metals, particularly to the United States, cannot be predicted at this time.

Recently, an international trading company acting on Chrysler's behalf negotiated a contract with the Soviet Union for the delivery in 1974 of 100,000 troy ounces of palladium.

11.2.2.3 Canada

In Canada, the noble metals are obtained as by-products of nickel and copper mining conducted primarily by three companies -- International Nickel, Falconbridge Nickel Mines, Ltd., and Consolidated Canadian Faraday, Ltd. As indicated in Table 11-1, the Canadian production in 1971 was approximately 468,000 troy ounces. The platinum-to-palladium ratio of the Canadian ore is about 1:1. Production is concentrated in the Sudbury basin of Ontario and the Thompson-Wabowden area of Manitoba (Ref. 11-3). Most of the noble metal concentrate is shipped to England and Norway for final refining, and the pure metals are then returned to Canada for export, primarily to the United States. The distribution of most of the Canadian noble metals in the United States is handled by Engelhard Minerals and Chemicals Corporation. Since the noble metals are by-products of nickel-copper mining, Canadian noble metal production cannot be significantly increased in the near future. Based on recent estimates by the Bureau of Mines, the annual production of noble metals in Canada will gradually rise to about 600,000 troy ounces in 1980 (Ref. 11-3).

11.2.2.4 Colombia

In Colombia, noble metals are being mined by the International Mining Corporation at a rate of approximately 25,000 troy ounces per year (90% platinum). The concentrated ore is then shipped to the United States for refining and is marketed through various dealers. The Colombian production is not expected to vary significantly in this decade.

11.2.2.5 United States

The total primary noble metal production in the United States in 1971 was only 18,000 troy ounces. Approximately half of that was mined by the Goodnews Bay Mining Company in Alaska and the other half was recovered as by-products from copper and gold refining operations in Maryland, New Jersey, Utah, Texas, and Washington. No significant increase in noble metal production is expected in this decade.

Noble metal recovery from scrap represents a significant source of supply in the United States. In 1971, approximately 278,000 ounces of noble metals were recovered from scrap, which amounts to about 20% of the total United States industrial demand. If noble metal prices increase as the result of the projected demand by the automotive industry, processing of scrap of presently marginal value may also increase.

11.2.2.6 Other Producers

As indicated in Table 11-1, the noble metals production in Ethiopia, Finland, and the Philippines is very small and has no significant impact on noble metals supply and demand considerations.

11.2.3 Noble Metal Reserves

The noble metal reserves in the world, as estimated by the Bureau of Mines (Ref. 11-1), are presented in Table 11-3.

Table 11-3. Estimated Noble Metal Reserves in the World

Country	Million Troy Ounces
Republic of South Africa	200
Soviet Union	200
Canada	16
Colombia	5
United States	3

The recoverable noble metal reserves in Africa are currently estimated at 200 million ounces. Recent discoveries in the Merensky Reef region of South Africa indicate that the total reserves may actually be significantly larger. In addition, recent explorations in the Great Dyke area of southern Rhodesia revealed several significant noble metal deposits (estimates range as high as 100 million troy ounces). With the exception of Ethiopia, where small quantities of platinum have been mined for many years, no additional noble metal deposits are currently known in Africa.

11.2.4 Noble Metal Production in South Africa -- By Company

As previously stated, South Africa is the largest producer of noble metals in the free world and the largest producer of platinum in the world. Since the future noble metal sales by the Soviet Union cannot be accurately predicted, primarily South African noble metals are required to satisfy the projected needs of the automobile industry in the United States in the post-1974 time period. For these reasons, a more detailed evaluation of the current and projected noble metal production capacity of the various South African mining companies is considered appropriate.

The latest information relative to the current and projected noble metals and platinum production capacities of the five largest South African noble metal mining firms is presented in Tables 11-4 and 11-5 (Ref. 11-3). Table 11-4 shows the estimated annual capacities and production rates of these mines. As indicated, the noble metal output of the leading mine (Rustenburg) is currently less than 50% of full capacity.

Table 11-4. Estimated 1972 Capacity and Production of South African Noble Metal Mines (thousand troy ounces)

Mining Company	Annual Capacity		Actual Production	
	Noble Metals	Platinum	Noble Metals	Platinum
Rustenburg Platinum Mines, Ltd.	1700	1200	800	500
Impala Platinum, Ltd.	600	350	500	350
Western Platinum, Ltd.	135	100	135	100
Atok Investment, Ltd.	18	11	18	11
Eland Mine	--	--	--	--
TOTAL	2453	1661	1453	961

Table 11-5. Projected Maximum Noble Metal Production Capacity of South African Mines(1) (thousand troy ounces)

Mining Company	1973	1974	1975	1976	1977	1978	1979	1980
Rustenburg	1700	2000	2200	2400	2600	2800	3000	3000
Impala	600	850	950	1050	1150	1250	1350	1500
Western Platinum	185	235	285	325(3)	375(3)	425(3)	475(3)	500
Atok	18	40	290	300(3)	300(3)	300(3)	300(3)	350
Eland	0	(2)	300	300(3)	300(3)	300(3)	300(3)	475
TOTAL	2503	3125	4025	4375(3)	4725(3)	5075(3)	5425(3)	5825

(1) Assuming commitments by the automotive industry with each mining company

(2) Some production possible in late 1974

(3) Approximate

The maximum production rates that could be achieved by these mines are shown in Table 11-5. However, these capacities will be obtained only if contracts are signed in the near future between the automobile manufacturers and the platinum mining companies. Without such commitments, it is unlikely that the mining companies would proceed with their projected expansion programs because of the large capital investment required for these projects. According to Matthey Bishop, Inc. (Ref. 11-4), more than $500 million would be needed to increase the annual noble metals output of the Rustenburg mines by 1 million troy ounces. These funds are required to cover the costs of the new shafts, new refining plants, and education and training of the laborers required to operate these plants.

11.2.4.1 Rustenburg Platinum Mines, Ltd.

Rustenburg is the world's largest platinum producer, controlling approximately 70% of the platinum production capacity in the free world. For economic reasons, the company operated at reduced capacity during the past several years. However, it is currently getting back toward full production because of the higher demand for noble metals resulting from the projected use of catalysts on the 1975 and later model year vehicles sold in the United States.

Rustenburg currently operates three mines, a smelter, and a refinery in the Transvaal District of South Africa. Another refinery is scheduled for completion in 1974. The company has proven reserves and a built-in expansion capability to provide over 3 million ounces of noble metals per year. Moreover, Rustenburg's parent company, Johannesburg Consolidated Investments, Ltd., holds mining rights to four other promising areas in South Africa's Merensky Reef region (Ref. 11-3).

Rustenburg has a preliminary 3-year contract (1975 through 77), through Engelhard, to supply 500,000 ounces of platinum annually to the Ford Motor Company. If the contract is firmed up (it currently has an escape clause), Rustenburg can clearly supply this amount of platinum. In addition, Rustenburg states that it could provide substantial quantities of platinum (and palladium) to other automobile companies without cutting supplies to nonautomotive buyers, provided commitments are received from the automotive industry before October 1972 (Ref. 11-6). These data are listed in Table 11-6.

Table 11-6. Rustenburg Platinum Quantities Potentially Available to the Automotive Industry (excluding Ford) (thousand troy ounces)

Year	1974	1975	1976	1977	1978	1979
Platinum Quantity	137	204	860	1200	1250	1200

11.2.4.2 Impala Platinum, Ltd.

As indicated in Table 11-5, Impala is the second ranking noble metal producer in South Africa. It acquired its Batokeng property in 1967 and completed the mine, mill, smelter, and refinery in 1969. In late 1970 the mine was producing platinum at a rate of several hundred thousand ounces per year. When the shafts were sunk for current production, Impala decided to drill additional shafts for future use. These shafts are currently being drained in anticipation of increased future noble metal sales. This illustrates Impala's capability of quickly expanding its production.

As indicated in Table 11-5, Impala's projected noble metal production capacity for 1973 is 600,000 ounces. If commitments are received from the automobile industry, the capacity of the mine could be increased to 850,000 ounces by 1974 and to 1.5 million ounces by 1980 (Ref. 11-3). In its latest annual report, Impala states that it could potentially supply 400,000 ounces of platinum for automotive use in 1974 and could increase delivery by 100,000 ounces per year until 1977 without curtailing its sales to other customers.

On September 21, 1973 General Motors announced a development contract with Impala that would prepare Impala to supply it with up to

300,000 troy ounces of platinum and 120,000 troy ounces of palladium a year for use in catalytic converters.

11.2.4.3 Western Platinum, Ltd.

Western Platinum is the third ranking producer of noble metals in South Africa. This company, which is jointly owned by Lonrho, Ltd. of England (51%), Falconbridge Nickel Company of Toronto, Canada (24.5%), and Superior Oil Company of Houston, Texas (24.5%), began production in 1971. Initially, two mines had been planned with a total capacity of 430,000 ounces of platinum by 1974/75 (Ref. 11-3). However, these plans have since been shelved as the price of platinum declined and as operational problems were encountered. As shown in Table 11-4, Western Platinum's current platinum production is approximately 100,000 ounces per year. By 1980 the platinum output of the mine could be increased to about 350,000 ounces, providing commitments are received in time from the automobile industry.

11.2.4.4 Atok Investment, Ltd.

Currently, Atok is a small noble metal producer with an annual noble metal capacity of about 20,000 ounces. The firm is jointly owned by Anglo-Transvaal Consolidated Investment Company, Ltd., U.S. Steel Corporation, and Middle Witwatersrand, Ltd. Apparently, the annual capacity of the mine could be increased to 40,000 ounces by 1974. If firm contracts are received in time, a new shaft, mill, and refinery could be added to increase the mine's annual noble metal production capacity to 290,000 ounces by 1975 (Ref. 11-3).

11.2.4.5 Eland Mine

This mine is jointly owned by Hanna Mining Company, Cleveland, Ohio and Amcor, Ltd. The noble metal reserves of this mine are sufficient for an annual production of 300,000 ounces by 1975. Eland feels that further expansion to approximately 475,000 ounces per year is feasible by 1980 (Ref. 11-3).

11.3 USAGE OF NOBLE METALS

11.3.1 EPA Study

Recently, the EPA conducted an in-house study to determine the quantity of platinum potentially required by the automotive industry for use in its projected 1975/76 vehicle emission control systems (Ref. 11-7). In this analysis, a number of assumptions are made by EPA, including the projected vehicle production rates, the noble metal loading of catalysts, and the number of catalysts used in each vehicle. Table 11-7 shows the projected production rates of 1975 model year vehicle/engine combinations used in the EPA analysis. These data are based on the Department of Transportation estimate of 11.4 million 1975 model year automobiles to be sold in the United States, and on the assumption that the engine size distribution in 1975 is equal to that in 1972.

Table 11-7. Projected 1975 Model Year Vehicle Distribution (in thousands)

Manufacturer	Number of Vehicles			Total Number of Vehicles
	4-cyl.	6-cyl.	8-cyl.	
General Motors	469.7	310.1	4409.5	5189.3
Ford	346.6	308.9	2069.1	2274.6
Chrysler	54.7	391.0	1126.3	1572.0
American Motors	0	165.3	96.9	262.2
Japanese	666.9	53.6	0	720.5
Other	788.9	79.8	62.7	931.4
Total Vehicles	2326.8	1308.7	7764.5	11,400.0

The automotive noble metal requirements for 1975 model year vehicles, listed in Table 11-8, were computed on the basis of the following assumptions (Ref. 11-7).

a. Oxidation catalysts are used on all vehicles.

b. Noble metal loading of the catalyst(s), as provided by a number of catalyst manufacturers.

c. Vehicle/engine distribution from Table 11-7.

Table 11-8. Predicted Automotive Noble Metal Requirements for 1975 Model Year Vehicles(1) (thousand troy ounces)

Noble Metal Loading Data Source	Noble Metal Requirement			Total Noble Metal Requirement
	4-cyl.	6-cyl.	8-cyl.	
Company A(2)	115	71	590	776
Company B	119	79	776	974
Company B, adj.(3)	119	79	975	1173

(1) 11.4 million vehicles

(2) All-platinum catalyst

(3) Adjusted to reflect higher catalyst noble metal loading for engine displacements above 400 CID

As indicated in Table 11-8, the predicted total noble metal requirement for 1975 model year vehicles varies between about 770 thousand troy ounces (Company A) and 1.2 million troy ounces (Company B, adjusted). As a further refinement of its prediction calculations, EPA has considered the following options for 1975 model year vehicles.

Option 1. Ford utilizes an extra catalyst on its 8-cylinder engines. The noble metal loading of this catalyst is assumed to be twice that of the two catalysts considered for V-8 engines.

Option 2. Ford uses the extra catalyst; General Motors uses an all-base metal oxidation catalyst instead of a noble metal catalyst. However, General Motors is considering promoted base metal catalysts for 1975; the all-base metal option was selected to determine the lowest platinum demand level.

Option 3. Ford does not use the extra catalyst; General Motors uses a base metal catalyst.

The total 1975 noble metal requirements computed for these options are presented in Table 11-9. As indicated the automotive noble metal demand for 1975 varies between approximately 400 thousand troy ounces (Company A; option 3) and 1.5 million troy ounces (Company B, adjusted; option 1).

Table 11-9. Predicted Total Automotive Noble Metal Requirements for 1975(1) (thousand troy ounces)

Noble Metal Loading Data Source	Total Noble Metal Requirement			
	Option 1	Option 2	Option 3	Option 4(2)
Company A(3)	933	558	401	776
Company B	1180	697	490	974
Company B, adj. (4)	1449	874	597	1173

(1) 11.4 million vehicles
(2) From Table 11-8
(3) All-platinum catalyst
(4) Higher catalyst noble metal loading for engine displacements above 400 CID.

As discussed in Section 3 of this report, the automobile manufacturers are currently considering reduction catalysts for NO_x control in 1976 and later model year vehicles. As a result, the noble metal and platinum requirements increase substantially between 1975 and the post-1975 time period. This is illustrated in Table 11-10 where the projected platinum requirements are listed for 1975 to 1980. The data in this table were computed on the basis of the following five ground rules.

a. Vehicle production increases by 200,000 units per year between 1975 and 1980 (11.4 million in 1975).

b. Equal noble metal loading for the oxidation and reduction catalysts.

c. In the case of Company B 70% of the total noble metal content of the oxidation catalysts is platinum. Company A utilizes all-platinum catalysts.

d. Ninety percent of the total noble metal content in the reduction catalysts is platinum.

e. No base metal catalysts are used.

Table 11-10. Projected Automotive Platinum Requirements (thousand troy ounces)

Example No.	Noble Metal Loading Data Source	1975	1976	1977	1978	1979	1980
1	Company A	776	1805	1837	1870	1900	1930
2	Company B	682	1586	1613	1642	1669	1698
3	Company B, adj.	821	1910	1942	1978	2010	2045
4	Company B 25,000-mile catalyst replacement; 90% platinum recovery	685	1610	1690	1775	1828	1860

Examples No. 1 through 3 in Table 11-10 are for new vehicles only and do not include the platinum required for catalyst replacement or catalytic retrofit systems which might eventually be used on pre-1975 model year vehicles. Example No. 4 is based on a catalyst replacement interval of 25,000 miles and 90% platinum recovery from spent catalysts. As indicated in Table 11-10, the predicted platinum requirements show only small variations in each calendar year (approximately ±10%).

11.3.2 Chrysler Study

Projected platinum usage data, provided by Chrysler (Ref. 11-8), are presented in Figure 11-1. These data include only the platinum required for automotive use (new vehicles and catalyst replacement on used cars) and were computed by Chrysler on the basis of the following assumptions:

a. 10.6 million cars per year (no expanding car production volume).

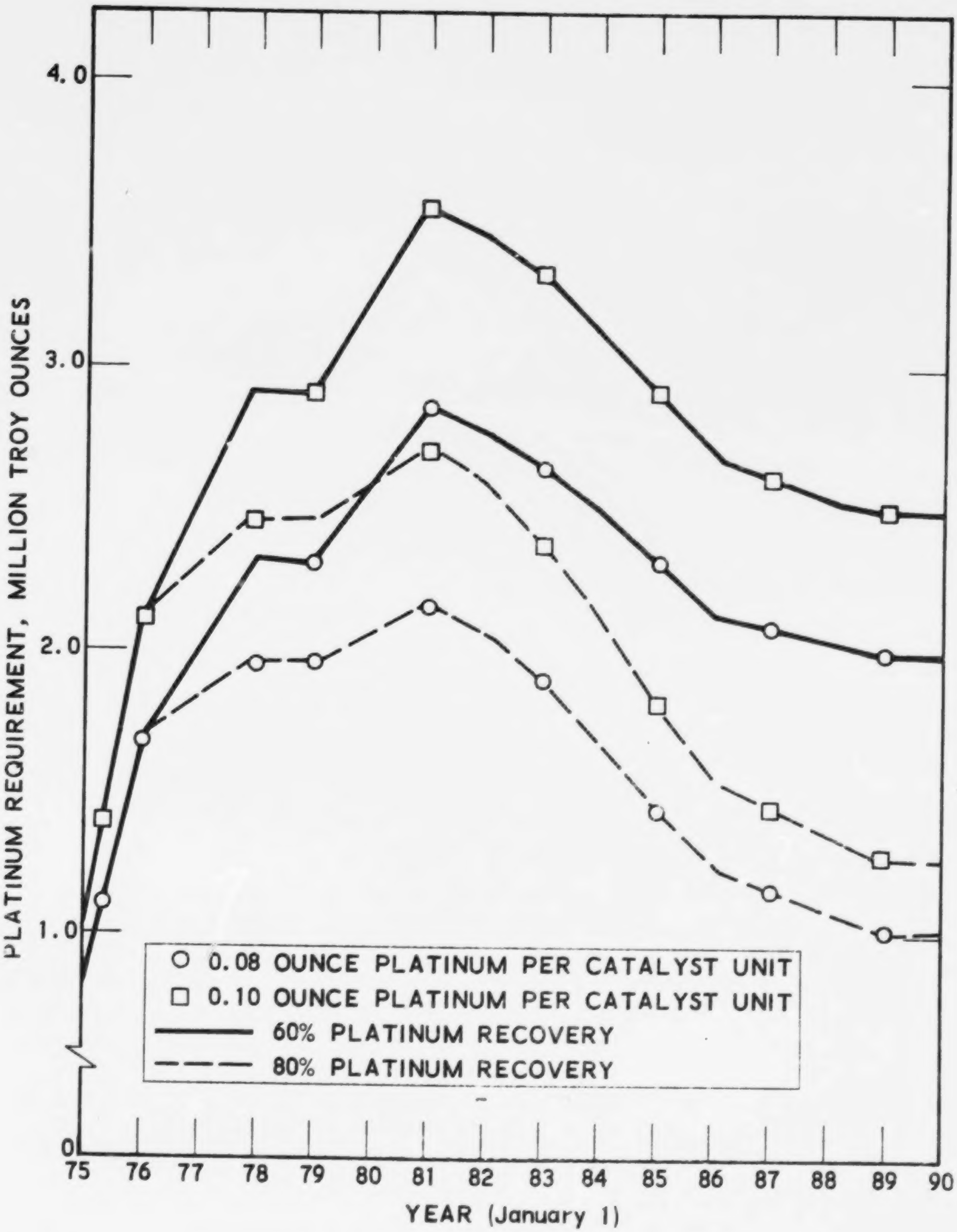


Figure 11-1. Projected Platinum Usage (Ref. 11-8)

b. One catalyst in 1975 using 0.08 or 0.10 ounce of platinum per car; two catalysts after 1975 using 0.16 or 0.20 ounce of platinum per car.

c. Car scrap rate from AMA data.

d. Car mileage 13,000 miles the first year with a linear decrease to 7000 miles for the tenth year.

e. 25,000-mile catalyst replacement interval.

f. 60% and 80% platinum recovery (scrapped cars included).

Based on these assumptions, the critical time period is between 1980 and 1982. Obviously, the platinum requirement is strongly affected by the noble metal loading of the catalysts and the catalyst replacement interval.

11.4 NOBLE METAL SUPPLY-DEMAND CONSIDERATIONS

This section provides information regarding the projected noble metal and platinum supplies available for automotive applications in the 1975 to 1983 time period. The supply data are compared with projected demand figures which were computed on the basis of several different assumptions.

11.4.1 Noble Metal Availability

Projected noble metal supply and demand balance data for 1971 through 1983 are listed in Table 11-11. The data for 1971, 1975, and 1980 were provided by the Bureau of Mines (Ref. 11-3) and were used to determine the noble metal and platinum supply and demand for each year between 1971 and 1983.

The maximum South African noble metal production capacities (assuming commitments from the automobile manufacturers) between 1972 and 1980 were previously presented in Table 11-5. With respect

Table 11-11. Projected Noble Metal Supply and Demand (thousand troy ounces)

Year	1971[1]	1972	1973	1974	1975[1]	1976	1977	1978	1979	1980[1]	1981	1982	1983
Noble Metal Production													
Republic of South Africa[2]	1,253	1,453	2,503	3,125	4,025	4,375	4,725	5,075	5,425	5,825	5,825	5,825	5,825
Soviet Union	2,300	2,400	2,510	2,625	2,750	2,900	3,050	3,200	3,400	3,500	3,700	3,900	4,100
Canada	468	475	480	490	550	560	570	580	590	600	610	620	630
Colombia	26	26	26	26	26	26	26	26	26	26	26	26	26
United States	18	18	19	19	20	21	22	23	24	25	26	27	28
Others	12	12	12	12	12	12	13	13	14	15	15	16	16
Total Noble Metal Production	4,077	4,384	5,550	6,297	7,383	7,894	8,406	8,917	9,479	9,991	10,202	10,414	10,625
Primary Demand, Non-U.S.	3,089	3,222	3,360	3,505	3,655	3,815	3,975	4,150	4,325	4,510	4,710	4,915	5,130
Noble Metals Available to U.S.	988	1,162	2,190	2,792	3,728	4,079	4,431	4,767	5,154	5,481	5,492	5,499	5,495
Nonautomotive Primary U.S. Demand	988	1,015	1,040	1,070	1,100	1,130	1,160	1,195	1,230	1,265	1,300	1,335	1,375
Available for Automotive Use	0	147	1,150	1,722	2,628	2,949	3,271	3,572	3,924	4,216	4,192	4,164	4,120
Additional Oil Industry Demand[3]	0	0	0	100	100	100	100	100	100	100	100	100	100
Noble Metals Available for Automotive Catalysts	0	147	1,150	1,622	2,528	2,849	3,171	3,472	3,824	4,116	4,092	4,064	4,020
Platinum Available for Automotive Catalysts	0	105	819	1,155	1,800	2,025	2,255	2,465	2,720	2,925	2,910	2,890	2,860

[1] Bureau of Mines Data

[2] Assumes Commitments to all South African Noble Metal Companies

[3] Bureau of Mines Estimate

to the post-1980 time period, the assumption is made that the noble metal production capacity in South Africa remains constant at the 1980 level. The capacity of the other countries and the nonautomotive demand for noble metals in the world are assumed to increase steadily during the 1971 through 1983 time period. The platinum quantities available for use in automotive catalysts were computed by multiplying the automotive noble metal figures in Table 11-11 by the factor 0.712 (platinum-to-noble-metal ratio in South African ore) and subtracting the additional 100,000 ounces of noble metal required by the petroleum industry for the production of unleaded gasoline (Ref. 11-3). As shown in Table 11-11, the projected maximum platinum supply available for the manufacture of automotive catalysts increases from approximately 1.8 million troy ounces in 1975 to 2.9 million troy ounces in 1980. After 1980 the projected platinum supply decreases by approximately 20,000 ounces annually.

The data listed in Table 11-11 are based on the maximum production capacity of the South African mines. As previously stated, this requires firm contracts between the automobile manufacturers and all noble metal mining firms in South Africa. Without contracts, the total South African noble metal production in the 1975 to 1980 time period will be of the order of 2.5 million troy ounces (Ref. 11-3), and as discussed in Section 11.4.2, this would not be sufficient to satisfy the estimated needs of the automotive industry.

Projected platinum supply and demand data provided by Rustenburg (through Matthey Bishop) are presented in Table 11-12. Comparison with the corresponding Bureau of Mines data (Table 11-11) indicates good agreement for the post-1975 time period. However, between 1972 and 1975, the Rustenburg predictions are considerably lower than the data listed in Table 11-11.

Table 11-12. Rustenburg Free World Platinum Supply and Demand Projection (thousand troy ounces)

Year	Platinum Production	Nonautomotive Consumption	Platinum Available for Automotive Catalysts
1972	1,500	1,800	-300[1]
1973	1,780	1,650	130
1974	2,290	1,750	540
1975	2,810	1,850	960
1976	4,070	1,950	2,120
1977	4,510	2,050	2,460
1978	4,690	2,150	2,540

[1] Covered by stockpiled platinum

11.4.2 Evaluation of Noble Metal Supply and Automotive Demand

Accurate evaluation of the noble metal and platinum supply and demand balance is currently very difficult, because several factors related to automotive catalysts are still unresolved. These include the required platinum loading of oxidation and reduction catalysts, the number of catalysts used on the various vehicle/engine configurations, the selected catalyst replacement interval, the vehicle production rates in the post-1975 time period, and the feasibility of platinum (and palladium) recovery from spent automotive catalysts. To provide a means of assessing these factors in terms of platinum supply and demand, six different cases are analyzed, as shown in Table 11-13.

Case 1 in Table 11-13 is based on the assumption of a total catalyst platinum loading of 0.08 ounce for 1975 model year vehicles (oxidation catalyst(s) only) and 0.16 ounce for 1976 and later model year vehicles (oxidation plus reduction catalyst(s)), 60% platinum recovery from

Table 11-13. Noble Metal and Platinum Supply – Automotive Demand Balance (thousand troy ounces)

	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
Noble Metals Available for Automotive Catalysts(1)	147	1,150	1,622	2,528	2,849	3,171	3,472	3,824	4,116	4,092	4,064	4,020
Platinum Available for Automotive Catalysts(1)	105	819	1,155	1,800	2,025	2,255	2,465	2,720	2,925	2,910	2,890	2,860
Case 1												
Automotive Platinum Requirement	0	0	0	848	1,690	2,015	2,331	2,306	2,584	2,585	2,770	2,650
Annual Platinum Surplus	105	819	1,155	952	335	240	134	414	341	325	120	210
Cumulative Platinum Surplus	105	924	2,079	3,031	3,366	3,606	3,740	4,154	4,495	4,820	4,940	5,150
Case 2												
Automotive Platinum Requirement	0	0	0	1,060	2,115	2,519	2,917	2,893	3,227	3,554	3,463	3,313
Annual Platinum Surplus	105	819	1,155	740	-90	-264	-452	-173	-302	-644	-573	-453
Cumulative Platinum Surplus	105	924	2,079	2,819	2,729	2,465	2,013	1,840	1,538	894	321	-132
Case 3												
Automotive Platinum Requirement	0	0	0	1,060	2,115	2,304	2,471	2,457	2,589	2,699	2,576	2,376
Annual Platinum Surplus	105	819	1,155	740	-90	-49	-6	263	336	211	314	484
Cumulative Platinum Surplus	105	924	2,079	2,819	2,729	2,680	2,674	2,937	3,273	3,484	3,798	4,282
Case 4												
Automotive Platinum Requirement	0	0	0	685	1,610	1,690	1,775	1,828	1,860	-	-	-
Annual Platinum Surplus	105	819	1,155	1,115	415	565	690	892	1,065	-	-	-
Cumulative Platinum Surplus	105	924	2,079	3,194	3,609	4,174	4,864	5,756	6,821	-	-	-
Case 5												
Automotive Platinum Requirement	0	0	0	848	1,695	2,525	3,340	3,340	4,110	4,890	4,890	4,890
Annual Platinum Surplus	105	819	1,155	952	330	-270	-875	-620	-1,185	-1,980	-2,000	-2,030
Cumulative Platinum Surplus	105	924	2,079	3,031	3,361	3,091	2,216	1,596	411	-1,569	-3,569	-5,599
Case 6												
Automotive Platinum Requirement	0	0	0	690	1,375	2,055	2,720	2,720	3,350	3,975	3,975	3,975
Annual Platinum Surplus	105	819	1,155	1,110	650	200	-255	0	-425	-1,065	-1,085	-1,115
Cumulative Platinum Surplus	105	924	2,079	3,189	3,839	4,039	3,784	3,784	3,359	2,294	1,209	94

(1) Data from Table 11-11; assumes commitments to all South African platinum-group Metal Companies

spent catalysts, a 25,000-mile catalyst replacement interval, and the annual vehicle mileage and vehicle production numbers previously used in determining the curves shown in Figure 11-1. Based on the assumption of the noble metal production rates predicted by the Bureau of Mines (Table 11-11), there would be a growing excess supply of platinum (and other noble metals) available throughout the 1975 to 1983 time period.

Case 2 is similar to Case 1, except that catalyst platinum loadings of 0.10 and 0.20 ounce are utilized for the 1975 and the 1976 and later model year vehicles, respectively. In this case, sufficient platinum will be available through 1982, providing the excess capacity potentially available in the 1972 to 1975 time period is stockpiled for this purpose. Beyond 1982 there will be a growing annual platinum deficit (approximately 130,000 ounces in 1983). However, if small amounts of palladium are used in the catalyst formulation in place of platinum, the total available noble metal supply will be more than adequate for the manufacture of automotive catalysts in the 1975 to 1983 time period.

Case 3 is similar to Case 2, except that an 80% platinum recovery factor is utilized. As indicated in Table 11-13, there is a substantial annual platinum surplus except between 1976 and 1978. During that period, a small total platinum shortage of about 150,000 ounces is obtained which, however, can be easily covered by means of the projected overproduction in the 1972 to 1975 time period. Again, utilization of small amounts of palladium in place of platinum would completely eliminate any temporary production deficit.

Case 4 is based on the projected platinum requirement previously presented in Table 11-10, example 4. As shown in Table 11-13, a large oversupply of platinum is predicted in this case for the 1975 to 1980 time period. This is primarily the result of the high degree of platinum recovery (90%) used in this particular case.

Case 5 is similar to Cases 1 through 3, except that catalyst platinum loadings of 0.08 ounce per car and 0.16 ounce per car, respectively are used for the 1975 and post-1975 model year vehicles. Furthermore, this case assumes zero platinum recovery from spent catalysts. As indicated in Table 11-13, the available platinum supply is adequate through 1980, providing the platinum is stockpiled during the 1972 to 1975 time period. At that point, platinum recovery from spent catalysts would have to be instituted in order to cover the annual platinum deficit of approximately 2 million ounces predicted for the post-1980 years.

In Case 6, the total catalyst platinum loading is 0.065 ounce for 1975 vehicles, and 0.13 ounce for 1976 and later model year vehicles, and the platinum recovery factor from spent catalysts is zero. All the other parameters are identical to those used for Cases 1 through 3. The data in Table 11-13 indicate that sufficient quantities of platinum are available in this case to satisfy the needs up to 1983, providing the full projected noble metal production capacity of the South African mines is maintained throughout the 1972 to 1983 time period.

The platinum surplus predicted for these six cases is reduced somewhat if the platinum production rates projected by Rustenburg (Table 11-12) are used instead of the Bureau of Mines data (Table 11-11).

11.5 CONCLUSIONS

Based on the analysis of the projected platinum and noble metal availability and requirements, the following conclusions are presented:

a. The current noble metal and platinum production capacity in the world is not sufficient to satisfy the projected requirements of the automotive industry in the United States in the post-1975 time period.

b. Most of the platinum required for the projected catalytic converter systems in 1975 and later model year automobiles must be supplied by South Africa. The production capacity in other countries is generally related to nickel and copper mining operations and can not be sufficiently increased to satisfy the potential demands of the automotive industry.

c. In order to assure adequate platinum availability in the 1975 to 1980 time period, contract agreements must be signed in the near future between the automobile manufacturers and the South African noble metal mining firms.

d. Platinum recovery from spent automotive catalysts may be required by 1980 unless the platinum loading of the catalysts is reduced from currently projected levels.

e. Platinum recovery from spent catalysts would not be required in this decade, if less than 0.16 ounce of platinum is utilized on the average 1976 and later model year vehicles and if the catalyst replacement interval is 25,000 miles or higher.

f. The platinum quantities available for automotive applications may not be sufficient to satisfy the needs of future catalytic retrofit systems which might eventually be used in pre-1975 automobiles.

g. The platinum (and noble metal) supply-demand balance is determined by the platinum (noble metal) loading requirement of the automotive catalysts, the number of catalysts required on the various vehicle classes, the catalyst replacement interval, the mining industry capacity, and the degree of platinum recovery from spent catalysts. A thorough study of these parameters is urgently needed in order to provide all the data required for a complete and meaningful assessment of the platinum and noble metal availability and demand balance.

REFERENCES

11-1. Mineral Industry Survey, Platinum Quarterly; U.S. Department of the Interior, Bureau of Mines, Washington, D.C., September 1, 1972

11-2. Robert W. Ageton and J. Patrick Ryan, "Platinum Group Metals," published in Mineral Facts and Problems, Bureau of Mines Bulletin No. 650, 1970 edition

11-3. Francis C. Mitko, "Availability of Platinum Group Metals for Use in Automobile Emission Control Devices," preliminary Bureau of Mines report.

11-4. Personal communication with Matthey Bishop personnel, October 5, 1972

11-5. Personal communication with W. R. Grace, August 21, 1972

11-6. Note on Schedule of Estimated Platinum Availability for Automotive Industry and Rustenburg Platinum Mines' Capital Expenditure; informal Rustenburg submittal to the Bureau of Mines

11-7. P. Staltman, "Platinum Supply and Demand Considerations," In-house EPA report

11-8. Aerospace/EPA visit to Chrysler Corporation, August 4, 1972

APPENDIX A

COMPANIES VISITED

In a 2-month period (August 1 to October 5, 1972), 32 domestic firms were visited in addition to one government automotive procurement agency. Three of these firms have primary business operations outside of the automotive industry while 11 others are new to the automotive industry by virtue of their potential for supplying products that make up the catalytic converter for the automobile emission control system. Three other firms produce specialized equipment that is relatively new to the automotive industry. The balance of 15 firms are heavily involved in the automotive industry as automobile producers or as suppliers of traditional components and production equipment and tooling.

In this appendix will be found a list of the companies visited, arranged in chronological order, along with an example of the company product line.

Date of Visit	Company Name	Example of Product Line
August 1, 1972	Budd Company, Automotive Division Troy, Michigan	Wheels, brakes, dies, and tools
August 2, 1972	American Motors Corp. Detroit, Michigan	Automobiles
August 3, 1972	Joseph F. Lamb Co. Warren, Michigan	Assembly and machine equipment
August 4, 1972	Chrysler Corporation Detroit, Michigan	Automobiles
August 9, 1972	Monsanto Company St. Louis, Missouri	Pellet catalyst
August 10, 1972	General Motors Corp. General Motors Technical Center Warren, Michigan	Automobiles
August 15, 1972	Reynolds Metals, Primary Metals Div. Richmond, Virginia	Catalyst substrate
August 17, 1972	Hayes-Albion Corp. Jackson, Michigan	Exhaust systems
August 18, 1972	Kelsey-Hayes Co. Romulus, Michigan	Stampings, forgings
August 21, 1972	Eaton Yale & Towne Co. Battle Creek, Michigan	Engine valves
August 21, 1972	W. R. Grace Co. Davison Chemical Div. Clarksville, Maryland	Monolith and pellet catalyst
August 22, 1972	Cross Company Fraser, Michigan	Assembly and machine equipment
August 22, 1972	Electron Research Corp. Santa Ana, Calif.	Electron beam welding equipment

Date of Visit	Company Name	Example of Product Line
August 23, 1972	AMF, Inc. Versatran Division Warren, Michigan	Programmed manipulators
August 23, 1972	Oxy-Catalyst, Inc. West Chester, Pa.	Pellet catalyst
August 24, 1972	U. S. Army Tank Automotive Command Michigan Army Missile Plant Warren, Michigan	Government truck and jeep procurement agency
August 25, 1972	Gulf Oil Corp. Research & Development Pittsburgh, Pa.	Pellet and monolith catalyst
August 29, 1972	Corning Glass Works Technical Products Div. Corning, New York	Catalyst substrate
August 30, 1972	Universal Oil Products Purzaust Department Des Plaines, Illinois	Pellet and monolith catalyst
September 1, 1972	American Lava Corp. Chattanooga, Tenn.	Catalyst substrate
September 6, 1972	Kaiser Chemicals, Div. of Kaiser Aluminum & Chemical Corp. Baton Rouge, La.	Catalyst substrate
September 8, 1972	Outboard Marine Corp. Milwaukee, Wisconsin	Small gasoline engines
September 11, 1972	Wean United, Inc. Youngstown, Ohio	Welding equipment
September 12, 1972	Westinghouse Corp. Columbus, Ohio	Home appliances

Date of Visit	Company Name	Example of Product Line
September 13, 1972	Hamilton Standard Div. United Aircraft Corp. Windsor Locks, Conn.	Electron beam welding equipment
September 15, 1972	Gilman Engineering & Manufacturing Co. Janesville, Wisconsin	Automatic welding equipment
September 18, 1972	Ford Motor Company Dearborn, Michigan	Automobiles
September 19, 1972	Borg-Warner Corp. Warner Gear Div. Muncie, Indiana	Automatic transmission
September 19, 1972	Engelhard Minerals & Chemical Corp. Newark, New Jersey	Monolith catalyst
September 20, 1972	Onsrud Machine Works Niles, Illinois	Milling machine equipment heavy duty presses
September 21, 1972	Greenlee Bros. & Co. Div. of Ex-cell-o Corp. Rockford, Illinois	Transfer machine equipment
September 22, 1972	General Electric Co. Louisville, Kentucky	Home appliances
October 5, 1972	Matthey Bishop, Inc. Malvern, Pa.	Monolith catalyst

APPENDIX B

BIBLIOGRAPHY

A list of documents that were acquired in the course of a literature survey for this study is presented in this appendix.

"Pacemakers In Component Design," Borg & Beck Division, Borg-Warner Corporation, *Automotive Industries,* 15 May 1963, p. 69.

"The Development of Tilt-Wheel Steering: From Conception to Finished Product," by Philip Zeigler, Saginaw Steering Gear Division, *General Motors Engineering Journal,* 4th quarter 1963, pp 2-6.

"Electronic Control System Improves Efficiency of Floor Pan Assembly Line Operations," by Dazo H. Ciranko and Arnold C. Lankenau, Fisher Body Division, *General Motors Engineering Journal,* 3rd quarter 1965, pp 23-31.

"Automation Plus at Lordstown," by R. H. Eshelman, *Automotive Industries,* 1 October 1970, pp 40-44.

"Building the Pinto Engine," by Peter Hoffmann, *American Machinist,* 16 November 1970, pp 75-77.

"Automated V8 Diesel Production," Perkins Engines, *Engineering,* 27 September 1968, p 478.

"Producing Ford's New 351 CID Engine," Part I, by Joseph Geschelin, *Automotive Industries,* 1 January 1970, pp 66-70.

"Producing Ford's New 351 CID Engine," Part II, by Joseph Geschelin, *Automotive Industries,* 15 January 1970, pp 52-56.

"Major Operations and Scheduling of Huge Dodge Truck Plant," by Joseph Geschelin, *Automotive and Aviation Industries,* 1 September 1946, pp 25-27 and pp 85-86.

"Modern Production Equipment Conspicuous at Studebaker Plant," by Joseph Geschelin, *Automotive and Aviation Industries*, 1 November 1946, pp 30-35 and pp 58 and 60.

"Development of the Annual New Car Model -- From Styling to Assembly," by Clarence E. Morphew, Cadillac Motor Car Division, *General Motors* Engineering Journal, July-August-September 1959, pp 32-38.

"Putting a New Car into Production," by Edward T. Ragsdale, Buick Motor Division, *General Motors Engineering Journal,* September-October 1953, pp 26-31.

"An Overall Look at the Toronado -- A New Breed of Automobile," by John B. Beltz, Oldsmobile Division, General Motors Engineering Journal, 1st quarter 1966, pp 2-8.

"Product Engineering in General Motors," by Harry F. Barr, Vice President in Charge of GM Engineering Staff, General Motors Engineering Journal, 1st quarter 1966, pp 9-10.

"Lead Time Practices," by Joseph Geschelin, Automotive Industries, 15 July 1967, pp 60-63.

"GM Desert Proving Ground," by D. S. Johnson, Engineering Operations, Automotive Industries, 1 November 1969, pp 63-65.

"Most Companies in Industry Now in Production of Cars to Some Degree," News of the Industry, Automotive and Aviation Industries, 1 November 1946, pp 46, 106, 108.

"Drive On to Attain Volume Car Production," by Leonard Westrate, Automotive and Aviation Industries, 1 September 1945, pp 17, 58.

"Return to Civilian Car Production Slow," by Leonard Westrate, Automotive and Aviation Industries, 15 August 1945, pp 17, 104, 106, 108.

"Finding New Ways to Make Autos," Business Week, 11 September 1965, pp 190-192, 194, 196, 198.

"Development of Assembly Procedures for the Toronado," by Donald R. Downie, Oldsmobile Division, General Motors Engineering Journal, 2nd quarter 1966, pp 35-42.

"Quality Control Aspects of Chrysler's Clean Air System," Part I, by R. L. Kessler, Manager, Products Quality, Automotive Industries, 15 August 1969, pp 60-68.

"How Carmaker Tackles Last Minute Design Change," by L. A. Kintigh, Director of Forward Planning, General Motors Corporation, Steel, 7 July 1969, pp 88d-88e.

"Many Areas Offer Opportunities for Cutting Lead Time," by E. C. Soistman, Martin Orlando, SAE Journal, September 1957, pp 76-77.

"A Summary of the Toronado Engineering Test Program," by Theodore N. Louckes and Charles L. Porter, Oldsmobile Division, General Motors Engineering Journal, 2nd quarter 1966, pp 29-33.

"Quality Control Aspects of Chrysler's Clean Air System," Part II, by R. L. Kessler, Manager, Products Quality, Automotive Industries, 1 October 1969, pp 74-75.

"Team Styling at Chrysler," by Elwood P. Engel, Vice President-Styling, *Automotive Industries,* 1 November 1969, pp 53-54.

"AM's Hornet -- A New Concept in Compacts," by William V. Luneburg, President, American Motors Corporation, *Automotive Industries,* 15 November 1969, pp 55-57.

"Shifting Trends in Plastics Process Developments," by J. O'Rinda Trauernicht, Assistant Managing Editor R & D, *Plastics Technology,* January 1970, pp 58-61.

"Ford Exhaust Emission Laboratory," by Allan Aitken, Director of Engineering, Ford Motor Company, *Automobile Engineer,* July 1971, pp 22, 25.

"Building the Chevrolet Vega," Automobile Engineer, November 1970, pp 456-461.

"The Design, Development, and Production of the Toronado Body," by Francis E. Smith, Fisher Body Division, *General Motors Engineering Journal,* 1st quarter 1966, pp 38-55.

Production of Motor Vehicles, by Henry M. Cunningham and William F. Sherman, McGraw-Hill Book Company, Inc., New York, 1951.

"Automotive Industrial Engineering Study," Final Report, PB 178 326, Arthur Young & Company, January 1968.

"Automotive Industrial Engineering Study: Volume I," PB 178 327, U. S. Department of Transportation, 31 December 1967.

"Automotive Industrial Engineering Study," PB 178 328, Booz-Allen and Hamilton, Inc., Detroit, Michigan, 12 March 1968.

The Man on the Assembly Line, by Charles P. Walker and Robert H. Guest, Harvard University Press, Cambridge, Mass., 1952.

"The Role of Prototypes in Development," by B. H. Klein, T. K. Glennan, Jr., and G. H. Shubert, Rand Corporation Report RM-3467/1-PR, April 1971.

"Proceedings of the First Planning Conference in the Problems of Introducing Change in the Automotive Industrial Engineering Process," PB 180 410, Johns Hopkins University, Baltimore, Maryland, 24 October 1967.

"Designing the Marlin," by Roy Abernethy, President of American Motors, Automotive Industries, February 15, 1965, pp 47-49.

"Critical-Path Scheduling," by John W. Mauchly, Mauchly Associates, Inc., Chemical Engineering, April 16, 1962, pp 140-154.

"Network Models for Project Scheduling - Part 1 - Planning Phase," by Borge M. Christensen, Manager, Special Systems Studies Computer Department, General Electric Co., Phoenix, Arizona, Machine Design, May 10, 1962, pp 114-117.

"Network Models for Project Scheduling - Part 2 - Preliminary Scheduling Phase," by Borge M. Christensen, Manager, Special Systems Studies Computer Department, General Electric Co., Phoenix, Arizona, Machine Design, May 24, 1962, pp 173-177.

"Network Models for Project Scheduling - Part 3 - Advanced Scheduling Phase," by Borge M. Christensen, Manager, Special Systems Studies Computer Department, General Electric Co., Phoenix, Arizona, Machine Design, June 7, 1962, pp 132-138.

"Network Models for Project Scheduling - Part 4 - Preparation of Network Model," by Borge M. Christensen, Manager, Special Systems Studies Computer Department, General Electric Co., Phoenix, Arizona, Machine Design, June 21, 1962, pp 155-160.

"Network Models for Project Scheduling - Part 5 - Preparing Computer Data," by Borge M. Christensen, Manager, Special Systems Studies Computer Department, General Electric Co., Phoenix, Arizona, Machine Design, July 5, 1962, pp 105-111.

"Network Models for Project Scheduling - Part 6 - Choosing a Plan," by Borge M. Christensen, Manager, Special Systems Studies Computer Department, General Electric Co., Phoenix, Arizona, Machine Design, July 19, 1962, pp 136-140.

"Applied Automation, A group of significant articles from the pages of Automotive Industries showing the application of modern Automation Techniques," by James R. Custer, Editor, Chilton Company Publishers, Philadelphia, published for Automotive Industries.

"'71 Buyers' Directory and Products Guide Issue," Chilton's Automotive Industries, December 15, 1970.

"Impact of Foundry Pollution," by Bernard S. Gutow, A. T. Kearney, Inc., Chicago, Illinois, Environmental Science & Technology, Volume 6, Number 9, September 1972, pp 790-793.

"Overtime and Productivity in Electrical Construction," by The National Electrical Contractors Association, March 29, 1973.

"Make-or-Buy Decisions in Tooling for Mass Production," by William A. Paton and Robert L. Dixon, Michigan Business Reports Number 35, Publication of the Bureau of Business Research, School of Business Administration, University of Michigan, 1961.

"The Automobile Industry Since 1945," Lawrence J. White, Harvard University Press, Cambridge, Mass., 1971.